VAN NOSTRAND'S

ENGINEERING MAGAZINE.

VOLUME XXV.

JULY—DECEMBER.

1881.

NEW YORK:
D. VAN NOSTRAND, PUBLISHER,
23 MURRAY STREET AND 27 WARREN STREET (UP STAIRS).
1881.

CONTENTS.

VOL. XXV.

VAN NOSTRAND'S

ENGINEERING MAGAZINE.

NO. CLI.—JULY, 1881.—VOL. XXV.

THE KINEMATICS OF MACHINERY.

By PROF. ALEX. B. W. KENNEDY, C. E., of University College, London.*

Lecture I.

Most of the models used to illustrate this and the following lecture belong to the Kinematic Collection of the Gewerbe-Akademie in Berlin, and have been designed by Professor Reuleaux, who is the Director of the Academy and a Professor in it. The rest were sent to the Loan Collection by Messrs. Hoff and Voigt of Berlin, and Messrs. Bock and Handrick of Dresden. In essentials there is no difference between the Berlin and the Dresden models. Both have been designed specially for use in instruction in the Kinematics of machinery.

I must first try to explain briefly, but exactly, what I mean by the phrase "Kinematics of machinery." Professor Reuleaux, whose models are before us, defines a machine as "a combination of resistant bodies so arranged that by their means the mechanical forces of nature can be compelled to do work accompanied by certain determinate motions." The complete course of machine instruction followed in some of the Continental technical schools covers something like the following ground:

First, there is the perfectly general study of machinery, technologically and teleologically. Then there comes what we may call the study of prime movers, which in terms of our definition would be the study of *the arrangements by means of which the natural forces can be best compelled to do the required work.* Then comes the study of what may be called "direct actors," or the direct-acting parts of machinery; in the terms of our definition, *the arrangement of the parts of a machine in such a way as best to obtain the required result.* Next comes what we call machine design; the giving to the bodies forming the machine the requisite quality of resistance. Machine design is based principally on a study of the strength of materials.

One clause of the definition still remains untouched. The machine, we said, does work *accompanied by certain determinate motions.* Corresponding to this we have in machine instruction the *study of those arrangements in the machine by which the mutual motions of its parts, considered as changes of position only, are determined.* The limitation here must be remembered; motion is considered only as a change of position, not taking into account either force or velocity. This is what Professor Willis long ago called the "science of pure mechanism," what Rankine has called the "geometry of machinery," what Reuleaux calls "kinematics," and what I mean now by the "kinematics of machinery."

The results of many years' work of Reuleaux in connection with this subject are embodied in his book *Die Theoret-*

* Abstract of lectures delivered at South Kensington.

ische Kinematik, which I recently had the pleasure of translating, and I shall endeavor to give you an outline of his treatment of the subject. It cannot be more than an outline, as you will readily understand. The subject is a very large one, and I have had to choose between taking up many braches of it and merely mentioning each, and confining myself to a few points, and going more into detail about them. I have chosen the latter plan, believing that the former would be of little benefit to anybody. It will be easy for those who are sufficiently interested in the matter to follow it up, and to study those parts which I omit, by the aid of the book I have just mentioned. My lecture to-day will be principally theoretical, and to-morrow I shall go more into practical applications. So far as possible, as I have Professor Reuleaux's models before me, I shall endeavor to follow his own order in treating the subject.

I presume you are acquainted, to a certain extent, with the ordinary method of studying "pure mechanism;" the method originated by Monge (1806), developed in Willis' well-known *Principles of Mechanism* (1841), and made popular, to a great extent, by Prof. Goodeve's capital little text book and others. Each mechanism is studied for and by itself, in general, by the aid of simple algebraic or trigonometric methods, and is spoken of in reference to a certain "conversion" of motion which occurs in it. Thus, we have the conversion of circular into reciprocating motion, the conversion of reciprocating into circular, &c., and simple formulæ express certain relations between the motions of two or more moving points. In this way we know something important about a great number of mechanisms, and arrive at many results which are both useful and interesting. Some things are still left wanting, however; and these things may be summed up in this way:

(1.) We notice at once that we have taken the mechanism as a whole. We do not *analyze* it in any way whatever, and therefore,

(2) We have scarcely any knowledge of its relations with other mechanisms, or (what is quite as important) of the various forms which one and the same mechanism may take. We shall see presently how extraordinarily various these forms are. We have never a *general* case with special cases derived from it; each case is treated by itself as a special one. Then

(3) The mechanism is studied in general from a point of view which gives us only the conditions of the motion of two points in it, or two portions of it, and is then left. The kinematic conditions of the mechanism *as a whole* remain absolutely untouched.

In such a mechanism as that of an ordinary steam engine, for instance, we study the relative motions of the guide block and the crank, or, I ought, perhaps, to say of the axes of the crosshead and of the crank pin. We thus know the motions of two points in the rod which connects those axes, the "connecting rod," but we leave the motions of its other points untouched. It may, of course, be said that these others are of much less practical importance. This is true to some extent, although their practical importance is greater than might be supposed at first. But in any case these motions must certainly be studied if we are to obtain a *complete* knowledge of the mechanism to which they belong. Any method of study, therefore, which covers all the kinematic conditions of the mechanism, instead of the mechanical conditions of two or three points only, possesses in that respect very great advantages.

The treatment of mechanisms which I shall sketch to you, is intended to remedy some of the defects which I have enumerated. Those of you who have studied modern geometry, side by side with the old methods, will recognize that these defects are somewhat analogous to those of Euclidean geometry. The attempt to remedy them proceeds in lines similar to those of modern geometry, and will eventually, I believe, when more fully worked out, take the same position in its own subject.

Let us, then, look first at the *analysis of mechanisms*. This is none the less important a matter that its results are so very simple in many cases. A clear understanding of those elementary matters is of great assistance in clearing up difficulties which occur in the more advanced parts of the subject.

In a machine or a mechanism of any

kind *the motion of every piece must be absolutely determinate at every instant.* It will be remembered that we are at present considering motion as *change of position* only, not in reference to *velocity.* The motion of change of position *may* be determined by the direction and magnitude of all the external forces which act on the body; the motion is then said to be *free*, but it is obviously impossible to arrange such a condition of things in a machine. The motions may, however, be made absolutely determinate independently of the direction and magnitude of external forces; and in order that this may be the case, the moving bodies, or the moving and fixed bodies as the case may be, must be connected by *suitable geometric forms.* Motion, under these circumstances, is called *constrained* motion.*

If I allow a prismatic block to slide down the surface of an inclined plane its motion will be free; it is determined by the combination of external forces which act upon the block. If the block be pressed on one side as it slides, it at once moves sideways, and can only be kept in a straight path if directly the pressure is exerted on the one side an equal and opposite force (or a force which has a resultant with the first in the direction of motion), be caused to act upon it on the other. If, on the other hand, the block be made to slide between accurately-fitting grooves (like a guide block in a machine), inclined at the same angle as the plane, and like it fixed, the block may be pressed sideways or in any other direction, but no alteration in its motion can take place; the motion is "constrained," it can occur only in the one direction permitted by the guiding grooves. In the one case the external force has to be balanced by another external force; in the other the balancing force is molecular, *i. e.*, is a *stress* and not an external force, and comes at once into play the instant the disturbing force is exerted. The geometric forms which are used in this way to constrain or render determinate the motions in machines are very various, and are chosen in reference to the particular motion required. If every point in a body be required to move in a circle about some fixed axis, a portion of the body is made in the form of a solid of revolution about that axis, and this is caused to "work in" another similar solid; the two forming the familiar pin and eye. If all points of a body be required to move in parallel straight lines we get similarly for guiding forms a pair of prisms of arbitrary cross section; a slot and block. If every point of a body be required to move in a helix of the same pitch we use a pair of screws of that pitch, one solid and one open, for constraining the motion—a screw and nut.

The *general* condition common to these very simple forms is that, in each case, *the path of every point in the moving body is absolutely determined at every instant*, that is to say, the change of position of the moving body is absolutely determinate.

The geometric name for these mutually constraining bodies is *envelopes*, and each one is said to envelope the other. We shall call them (kinematic) *elements*, and the combination of two of them we shall call *a pair of elements.*

Those we have mentioned are special and very familiar and important cases of pairs of elements, which are of great simplicity. They have the common property of surface contact, the one enclosing the other, and are therefore called *closed* or lower pairs of elements. They are, moreover, the only closed pairs which exist. They are, further, the only pairs in which all points of the moving element have *similar* pairs.

Every point of an eye, for instance, moves in a circle about the same axis. If there were attached to it a body of any size or form whatever, all its point would move about the same axis. The "point paths" would all be concentric circles. Again, whatever the external size or shape of a nut, every point in it moves in a helix of the same pitch about the axis of the screw; the point paths, that is, would be similar.

The general condition of determinateness of motion can, however, be fulfilled by an immense number of other pairs of elements. The theory of these is too large a subject to be entered into just now, I must merely direct your attention to the existence of such combinations.

* Essentially it does not differ from free motion; the difference really lies in the substitution of *stresses* or *molecular forces*, which are under our complete control, for external forces.

Fig. 1 represents one of the simplest that can be used. Here one of the elements is an equilateral triangle, ABC, the other is the "duangle" RPSQ.

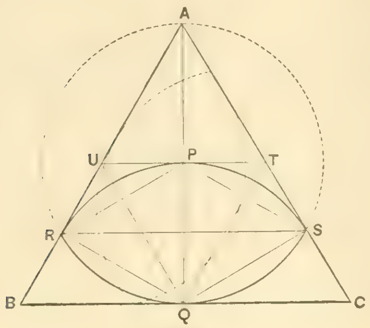


Fig. 1

The latter moves within the former, touching it always in three points, or rather along three lines. Its motion is just as absolutely determinate as the motion of a pin in an eye. It is free to move at any instant only about the point in which the three normals to the triangle at the points of contact intersect (as Q in the Fig.). The models before you show a few of the many forms taken by such pairs of elements. It is worth while noticing a few points in which the motions determined by them differ from the motions of the closed pairs. First, as we have already seen, the contact of the elements determining the motion was surface contact in the former case, while here it takes place only along a finite number of lines. Then the motions of all points in the first case were similar; in these pairs the motions of the points are not similar, but entirely dissimilar, the motion of each point depending entirely upon its position. Fig. 2 shows a few of the point paths of the pair of elements shown in Fig. 1. The strikingly different curves obtained from one pair of elements, according to the choice of the describing point, is too obvious to need further notice.*

These pairs of elements are called *higher pairs.* They have only a few applications in practice, their interest being chiefly theoretical. From our present point of view their theoretic interest is considerable, because of their exact analogy with the lower pairs.

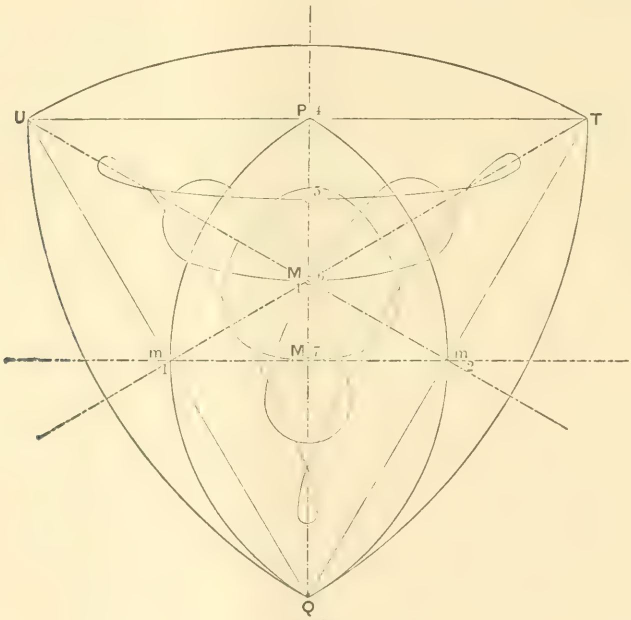


Fig. 2

There is another difference between the two kinds of pairs which deserves notice, for reasons which will be better

understood afterwards. The pair of elements determine the relative motion of the two bodies connected by them. If one body be stationary on the floor or the earth, the moving body has the same motion relatively to the floor or earth that it has to the other element. If I move about both bodies in my hand, both have motion relatively to the earth, but the relative motion of the one to the other remains unchanged. It is of course only a case differing in *degree* from the former one, for in the former one both bodies had the motion of the earth itself, while one had the additional motion which I gave it. We may, however, not to be pedantic, speak of anything as "fixed," or "stationary" which has the same motion as the earth.

Now, (in this sense) we may *fix* either element of a pair, and with the lower pairs the *relative motion taking place remains the same* whichever element be fixed. With the higher pairs, on the other hand, the relative motion is altered, and the point paths become entirely different. The point paths of the duangle relatively to the triangle are, for instance, quite different from those of the triangle relatively to the duangle. This change of the fixed element is called the *inversion* of a pair.

The ultimate result of our analysis of mechanisms is then pairs of elements; we cannot go below this. The pairs we have noticed are of two kinds, each having their own definite characteristics. If, now, two or more elements of as many different pairs be joined together we get a combination which is called a (kinematic) *link*. It is obvious that the form of such a link is, kinematically, absolutely indifferent. The choice of its form and material belongs to machine design. It may be brick and mortar, cast iron, timber, as we shall see afterwards, but the fact that this is indifferent, kinematically, cannot be too distinctly kept in mind.

We can make combinations of links by pairing the elements which each contain to partner elements in other links, and such combinations are called *kinematic chains*. Thus, if we denote similar elements by similar letters, *aa*, *bb*, *cc*, &c, and the link connection by a line, we may indicate some of the chains obtainable from 4 pairs and four links, thus;

a —— *bb* —— *cc* —— *dd* —— *a*

(we suppose the "chain" to return on itself and the two elements *a* to be paired, the whole forming a *closed chain*); or,

a —— *cc* —— *bb* —— *dd* —— *a*

or

a —— *dd* —— *cc* —— *bb* —— *a* &c.

For the sake of illustration we give in Fig. 3 a sketch of a familiar chain containing four links, each connected to the

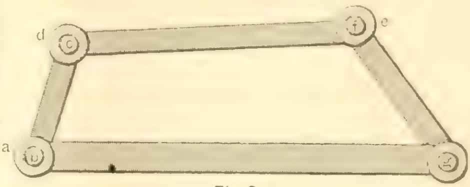


Fig. 3

adjacent link by a cylinder pair of elements. The axes of the four pairs of elements are parallel.

We have, then, in the kinematic chain, a combination so constructed that all its parts have determinate motions, motions absolutely fixed by the form of the elements carried by its links, and independent (considered as changes of position) of the application of external force. To convert the chain into a *mechanism* we have only to do what we have already done in connection with pairs of elements, fix one element—or, as each element is rigidly connected with a link, we may say preferably *fix one link*. Any link may be fixed, the chain, therefore, gives us as many mechanisms as it has links. In general these are different, in special cases only two or more of them are the same. We shall be able to enter into this part of our subject at some length in the next lecture; at present it will suffice to note two or three of the leading characteristics of chains and mechanisms which we can now easily recognize. These are,

(i.) That the motion of any link relative to either adjacent link is determined by the pair of elements connecting them.

* The triangle UTQ and the three curves within it, which have M_1 for their center, are point paths. The curve triangle and the duangle shown in thicker lines will be explained further on.

(ii.) That the motion of any link relative to any other than its adjacent links depends on *all* the elements of the chain.

(iii.) That no link of a *mechanism* can be moved without moving all the other links except the fixed one, and

(iv.) That there can be only *one* fixed link in a mechanism.

The two last propositions require a few words of explanation. Suppose that in any combination of, say, four links, two can be moved without moving the other two, the combination is actually one of three links only, for clearly the two immovable links may be made into one, and are two only in name. This is very often the case in machinery, where special mechanisms are frequently used for the express purpose of connecting rigidly two or more links, and making them act as one, at certain intervals.

If, however, in the combination supposed, one link be fixed, while two can be moved and the fourth can *either* move or be stationary, the combination no longer comes under our definition of *constrainment*, for the motions are at a certain point indeterminate, at the point, namely, when it is possible for the fourth link either to move or to stand. Chains often occur in which this would be the case were it not that mechanicians take means, either by adding other chains or in other ways, to constrain the motion which would otherwise be useless to them.

We have now obtained some idea of the way in which mechanisms are formed, of the elements of which they consist. Before applying the knowledge we have thus acquired I must direct your attention to some geometric propositions which will greatly facilitate the theoretic dealing with these mechanisms.

In order that I may not enter into too wide a subject, I shall confine myself here to the consideration only of "conplane" motions, or motions in which all points of the moving body move in the same plane or in parallel planes. The limitation is a large one, but the cases included under conplane motion cover the greater part of those which occur in practice. The method which I have to describe is equally applicable to general motion in space as to simple constrained conplane motions of which I shall speak.

Let me remind you that the motion of any *figure* moving in a plane is known if the motion of any two points (*i. e.* of a line) in it be known. The motion of any *body* having conplane motion is known if the motion of a plane section of it, parallel to the plane of motion, be known. Such a plane section of it is, of course, simply a plane figure moving in its own plane. The motion of any *body* having conplane motion (as in nine cases out of ten in machinery),c an therefore be determined by the determination of the motion of two points. In speaking now, therefore, of the motion of a *line* for shortness' sake, it must be remembered that we are really covering all cases of conplane motion of *solid bodies.*

In Fig. 4 PQ and P_1Q_1 are two positions of the same plane figure, or plane section of a body having conplane motion. If now we have two positions (in the same plane) of any plane figure, we know that the figure can always be moved from the one to the other by turning about some point in the plane. The position of the point O, about which the figure can be turned from the position PQ to the position P_1Q_1 can be found at once by the intersection of the normal bisectors to PP_1 and QQ_1. The motion of PQ in the plane is, of course, its motion relatively to the plane, and therefore relatively to any figure (as A B) in the plane. Such a point O as we have found here is called a *temporary center*, because the turning or motion takes place about it for some finite interval of time. It will be remembered that not only the two points and PQ of the figure, but every other point of it, must have a movement about this same point O at the same time. Now suppose we have some further position of the same figure, as for example at the position marked P_2Q_2, we can find in the same way the center about which the figure must be turned to move from P_1Q_1 to P_2Q_2. We may indicate this point as O_1. Similarly taking other positions of this figure P_3Q_3 and so on, we can find other points, O_2O_3, &c. By joining the points $OO_1O_2O_3$, we obtain a polygon, and if the figure in its motion come back to its original position the polygon also comes back on itself, and passes again through the point O. Such a polygon, whether it be closed in this way or not, is called a *central poly-*

gon; its corners are the temporary centers of the motion of the figure.

I have pointed out that all the points in the figure PQ move round O during the motion from PQ to P_1Q_1. They move round O necessarily through some particular angle, the angle POP_1, and every point moves through the same angle, which we may call φ_1. As the figure may have any form we choose, let us suppose it so extended as to contain a line which is the same length as OO_1, and which makes with OO_1 the angle φ_1, that is to say, the angle through which the figure moves about O. Such a line is shown in Fig. 4 by MM_1.

We have, then, a line MM_1 forming a part of the figure PQ, equal in length to OO_1, the points O and M coinciding, and the angle O_1MM_1 being $=\varphi_1$. Then when the figure has completed its motion about O, MM_1 and OO_1 must coincide. Take further similarly $M_1M_2=O_1O_2$ and so placed that when M_1 coincides with O_1, $< O_2M_1M^c=\varphi_2$, then when the figure takes its third position, completing the turning about O_1, M_1M_2 coincides with O_1O_2. Similarly we can obtain M_3M_4, &c. The figure thus found is another polygon, which we may call a *second central polygon.*

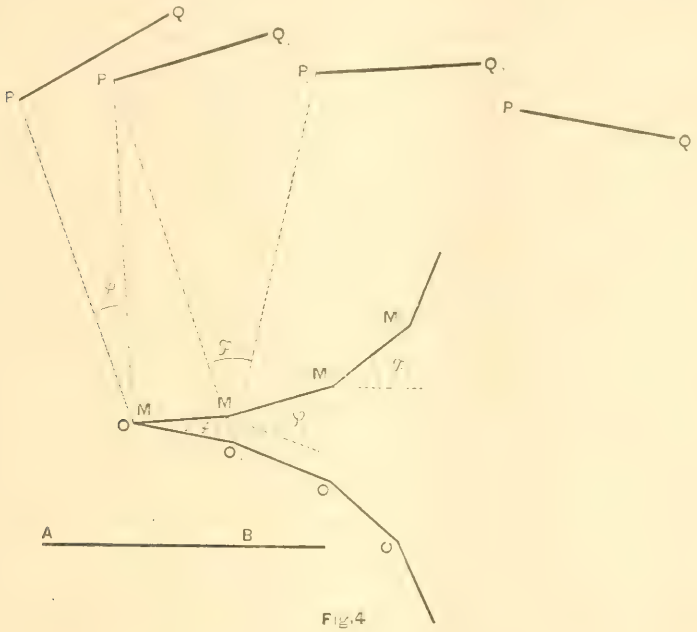


Fig. 4

These polygons have important properties, the principal of which can be very easily recognized. The first polygon does not alter its position during the motion of the body; it is therefore fixed, so that it may be considered *as a part of any figure such as* AB, which is fixed or stationary in the plane of motion. The second polygon moves with PQ *and forms* (by construction) *part of the same figure with* PQ. This second polygon then, by the consecutive turnings of its corners upon the corresponding corners of the first (and equal-sided) polygon, will give to PQ the required changes of position relatively to the fixed plane or to the figure AB lying in it.

If, therefore, we know the central polygons for the given motion, we know not only the changes of position of the points P and Q, but those of every other point connected with the moving figure, whatever form it may have. For at any one instant every point in the figure is moving about the same center. In studying the relative motions of the figures we may, therefore, quite leave out of sight their *form* if we only know the central polygons for the motion. These tell us, so far, all about the motion which is taking place.

We may go further, however. We have recognized the fact that the relative motion of two figures or bodies may take place equally whether one or the other of them be fixed, or both moving. In the case before us we have supposed AB fixed and PQ moving relatively to it. The second polygon then moves on the first, and expresses the relative motion taking place. If, however, we suppose PQ fixed and AB moving, then the polygons still express the relative motion; but the second is now fixed and the first rolls upon it. This follows directly from the constitution of the polygons. The properties of the polygons as expressing the relative motions of the bodies to which they belong are, therefore, reciprocal.

You will have noticed, no doubt, that the polygons do not express *continuous motion.* They define only a series of changes of position in their beginning and end, not telling us of the intermediate stages.

We may, however, take the consecutive position of the figures *as close together as we like.* The closer together they are taken the shorter become the sides of the polygons. If at last the distances PP_1, P_1P_2, QQ_1, &c., be taken *infinitely small*, each corner of the polygon will be *infinitely close* to the next one. That is to say the two polygons will become *curves*, and of these curves "infinitely small parts of equal length continually fall together after infinitely small rotations about their end points." In other words the two curves *roll* on one another during the continuous alterations in the relative position of the two figures. Instead of finding points now by the intersection of normal bisectors, they are found by intersection of *normals to the paths* of P and Q (Fig. 5). The turning about each point now occurs (not in general) for a finite period, but for *an instant* only. Each point is therefore called an *instantaneous center.* The curve containing all the instantaneous centers, or the *locus* of instantaneous centers, is called a *centroid.* Without giving them any special name, several writers on Mechanics have made more or less use of these curves. Among these I may mention Dwelshauvers-Dery, Schell and Pröll. Reuleaux has, however, given them a name (*Polbahnen*), and has made some special use of them, more, I think, than has been made by former writers.

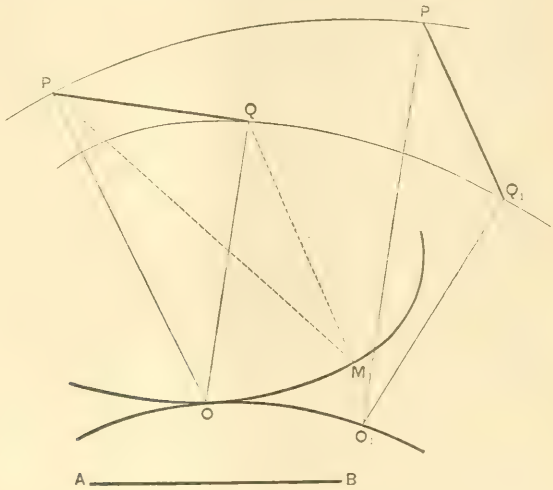


Fig.5

While the polygons only represent a series of isolated positions of a body, the centroids, rolling on each other, represent the whole motion continuously. Like the central polygons their properties are reciprocal. If then the centroids of two figures be known, their relative motions for a series of changes of position, each infinitely small, are also known,

i. e. their motions are *completely* determined.

If AB and its centroid be fixed, and the centroid of PQ rolled upon it (Fig. 5), we have now the means of determining the path of motion of every point in the Fig. PQ relative to AB, whatever may be the form of PQ. It is sometimes of great convenience to be able to find the motions of all points in a body in such a very simple way. Reciprocally we can determine the point paths of A B relatively to PQ, which, in general, differ entirely from those of PQ relatively to AB.

If *both* figures be moving, as frequently happens in practice, both centroids are also in motion; their motion relative to each other, however, remains unaltered. They still roll on one another, and their point of contact is still the instantaneous center of the motion of each relatively to the other. Each figure moves, relatively to the other, about this point, which being common to the two centroids, is common to the two figures. They might, therefore, for the instant, be connected at that point by a cylindric pair of elements. There are many problems of which the solution is greatly simplified by the recollection of this fact. The point in each figure which coincides with the instantaneous center, has, therefore, no motion relatively to the other figure. We have already seen this in the special case where the one figure is stationary, for then the point in which the moving centroid touches the fixed one is, by hypothesis, also stationary for the instant; in other words, it has no motion relatively to the fixed centroid. We now see the general condition of which this is a special case.

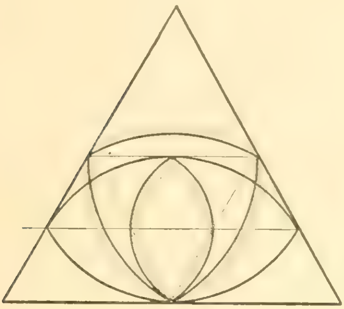


Fig.6

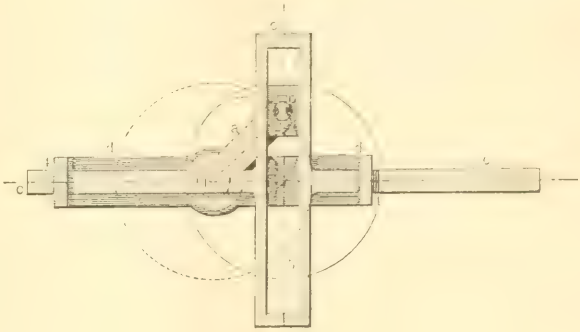


Fig.7

Fig. 6 shows the centroids for the higher pair of elements of Fig. 1. The curve triangle UTQ is the centroid of the triangle ABC, and the shaded duangle PVQW is the centroid of the duangle RPSQ.* As the duangle moves in the triangle (the elements *sliding* upon each other), its centroid *rolls* within the centroid of the triangle. Both centroids are in this case formed of arcs of circles, and all the point paths (being determined by the rolling of one circular arc upon another) are combinations of trochoidal arcs.

The centroids of kinematic chains are generally of greater complexity than those of the pairs of elements just mentioned, but in some cases are quite as simple. In Fig. 7, for example, is shown a mechanism familiar to engineers, in which a crank *a* drives a reciprocating bar *c* by means of a block *b* working in a slot. The centroids defining the relative motions of the links *a* and *c* are the two circles shown in full lines, one double the diameter of the other. These two circles both move as the mechanism works (supposing the link *d* to be fixed), but always so that they roll continuously one on the other. If instead of fixing *d* the crank *a* were made the fixed link, the same centroids would still express the relative motions of *a* and *c*. The smaller circle, the centroid of *a*, would be stationary along with the link to which it belongs, and the other would roll on it, the instantaneous center for the motion

* These centroids are shown on a larger scale, apart from the elements to which they belong, in Fig. 2

of the link c being always at their points of contact. This mechanism (a being fixed) is used in Oldham's coupling, in elliptic chucks, &c. Knowing these centroids we know all about the motions of the two corresponding links in the mechanism, not only about the motions of some particular points in these links.

The centroids of kinematic chains can in general be very easily determined. Once found they make us independent to a great extent of trigonometric or algebraic formulæ, and enable us to determine all we wish to know by purely geometric graphic constructions. For technical purposes, at least, this is frequently an immense advantage. There are very few cases in which it is not more convenient for the engineer to employ a construction than a formula, if both give him the same result.

Before looking at the centroids of other mechanisms, it is necessary to examine one particular case which often occurs. Suppose that the lines PP_1 and QQ_1 in Fig. 4, or the tangents to the curves at P and Q in Fig. 5, had been parallel. It is obvious that the normal bisectors in the one case and the normals to the curve in the other then become also parallel, or, as it is for some reasons more convenient to express it, would meet at an infinite distance. The temporary center in the one case and the instantaneous center in the other are at infinity. A centroid may, therefore, contain one or more points at an infinite distance, may have, that is, one or more infinite branches. This constantly occurs in mechanism, and in some cases *every* point in the centroid is at an infinite distance. This is, however, a special case; its treatment does not offer any practical difficulty, but I cannot do more than mention its existence here.

The centroids of the connecting rod and frame of the ordinary steam engine driving mechanism (the links b and d of Fig. 8) may serve as an illustration of this. When the crank a is at right angles to d, the normals to the paths of the two points 2 and 3 are parallel. The instantaneous center of b relatively to d is, therefore, at an infinite distance. Each centroid has, therefore, a pair of infinite branches.

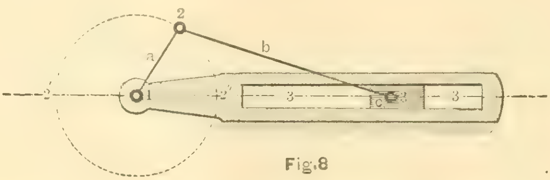


Fig. 8

We may look, in conclusion, at one other case which possesses some special interest on account of the form taken by the centroids. It is shown in Fig. 9. The chain contains four links and four parallel cylinder pairs. The alternate links are equal, and the two longer links are crossed so that the chain forms an "anti-parallelogram" in every position, the angle at 2 being always equal to that at 4, and the angle at 1 to that at 3. If the link d be fixed, the links a and c become two cranks which revolve in opposite directions with a varying velocity ratio. The centroids of b and d are a pair of hyperbolæ having their foci at 2 3 and 1 4 respectively. The one rolls upon the other as b moves, the instantaneous center in the position shown being at the point of contact O, which is the point of intersection of 1 2 and 3 4. The centroids of the two shorter links are the two ellipses which are shown in dotted lines. They are confocal with the hyperbolæ, and their point of contact is always at the intersection of 1 4 and 2 3. Their form shows at once that the rotation of the axes 1 and 4 is precisely the same as that which would be communicated by a pair of elliptic spur wheels having the centroids for their pitch ellipses.

In this mechanism, as in some of the others illustrated, the centroids of two *adjacent* links, as a and d, or b and c, are simply a pair of coincident points which

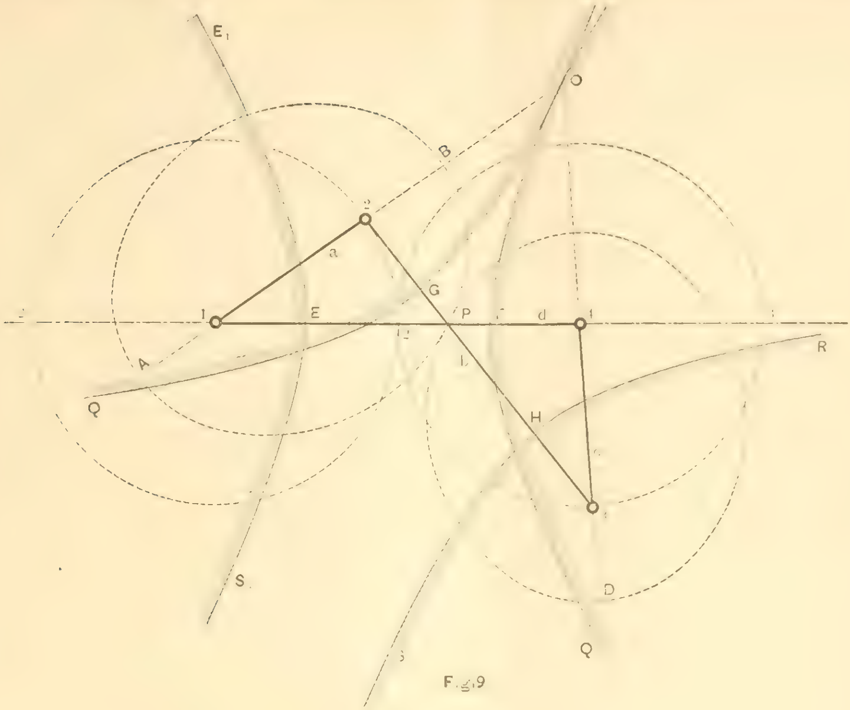


Fig. 9

roll upon each other. They form thus a limiting case of centroids, but every theorem which applies to the more extended centroidal curves applies also to these points, as can easily be seen on examination.

NOTES ON RAILROADING.

By H. P. BELL, Can. Pac. R'y.

Written for Van Nostrand's Engineering Magazine.

Under the head of railroading a valuable paper appeared in the April issue of this magazine. Speaking of the engineer's equipment for an exploratory survey the author says: "It need only consist of an ax, a pair of field glasses, a hand level, or two barometers, and a pair of steel climbers."

If the distance over which the exploratory survey is to extend be greater than the author of this paper seems here to contemplate, it will be found, in most cases, better to equip as follows: One hand level, one ship's sextant, one chronometer, one good pocket compass, one epitome of navigation and one book of mathematical tables—barometers optional.

In keeping a traverse or track survey with lateral sketching, it will be found useful for after reference to fix a number of points by observation. Not all engineers understand well how to use a sextant, and a few hints may be useful. Never assume the index error as constant, but try it before each observation. Always correct, if necessary, with the key the adjustment of the horizon glass, and every night that a star can be seen, see that the optical axis of the long telescope is parallel with the plane of the instrument. Do not observe without

using the long telescope, as a good contact cannot be otherwise made. Get a canvas cover made for the sextant box. Take one tin plate from the cooking outfit, and use this with a little water and a piece of Indian ink to make an artificial horizon, carry the plate under the canvas cover on top of the lid of box. The explorer can stop either in the morning, or more conveniently in the afternoon, and having worked his latitude, by dead reckoning, from the last mid-day observation, he can take the time at the place by obvervation, and work up his longitude just as at sea. Tree-top sketching, by the aid of the hand level and compass will soon make an explorer very independent of barometers, whose results, with the greatest care, are sometimes very uncertain. If the distance of survey be short, and any sort of map in existence, a smart explorer, by the aid of a sextant, without a chronometer, can make a chart of his work so true that he can always feel his way over the same ground again in any direction, and strike or avoid well-defined points, as desired, with preliminary line. I will omit reference to all those portions of Mr. Waddell's paper as unexceptionable, until he begins to describe the work of the levelers on preliminary line, in which he states that they should never approach the transit closely enough to disturb the back picket; and I would remark in this connection, that in overcoming great differences of level it is sometimes necessary to run grade upon a side hill for many miles continuously.

In such a case it will be better to put the leveler tight up to the back chainman, the chainman close to the axman, and the transit behind. The chief of the party can turn the angles with pickets as the leveler calls out to him how he is going by grade, and the transit man can make a traverse through the chopping. As the leveler marks his relation to grade frequently on the stakes, the back leveler or topographer can take note of that, and cross-section its amount out to grade, so that it may be possible afterwards to trace on the plan a complete contour line in the plane of the grade. In running grade on a side hill, the tendency will be to exaggerate the true length by preliminary line about ten per cent., so that if it be desired to locate a grade of one foot on the hundred, it will be best to run a grade of $\frac{9}{10}$ of a foot per 100 feet on the preliminary line. Coming to that part of the author's paper in which he states his preference for a Pastorelli level, I would say (as the result of practice with many different kinds of levels) that the instrument made by Spencer & Sons, Grafton street, Dublin, mounted upon an American tripod, head and legs, with only three screws in the parallel plate, will please almost any man. I would prefer the Y, as improved, to the dumpy, for the reason that the Y adjustments more combine theory with all the excellence of adjustment practically possible, than the other form of level. I say three screws in the parallel plates, because a plane will coincide with each one of any three points, in any position, but not with each one of four.

Further on, the writer makes the remark that leveling can be done very rapidly in writer, as traveling on snow shoes is so much easier than ordinary walking.

This requires explanation. It will be easier in certain places and at certain times. In other places and for long periods it will be easier to walk five miles in boots in summer than to break your own track for one mile on snowshoes. Further on, the author says of the transit man that if there be not a topographer, the transit man must keep full topographical notes, either side of the line by offset. Experience has proved that in a bush country the transit man who does this will consume more of staff and axman's time than would pay for two topographers, and, therefore, for economical reasons, in a close country topographers are a *sine qua non.*

Passing on to that portion of the author's paper in which he speaks of recording an angle to the wrong side, it may be remarked that this is quite possible, if the transit book be kept on the right and left angle principle, probably the most dangerous known. But if all angles be read from the meridian, which is done practically by keeping the back reading on the plate when the instrument is moved forward, the chances of error will be infinitesimally small. Otherwise, take one of Gurley's transits divided in four quadrants and full circle besides. Grind off the variation so as to make the needle read zero when the plates are set at zero

on the true meridian. Read the line bearings on the quadrant, and full circle besides, then look at the needle after. The chances of error will be reduced to the lowest point, and the probability of discovering an error, should one be made, will be raised almost to certainty. Many men dislike this system as involving too much work, but it saves time in the long run, and those who have used it never regret.

Further on the author of the paper referred to, says: "Locations are sometimes made by taking the angles and distances directly from the plot and laying them out on the ground, but the ordinary way is to use the plot simply as a guide, to run in the tangents and put the curves in to suit."

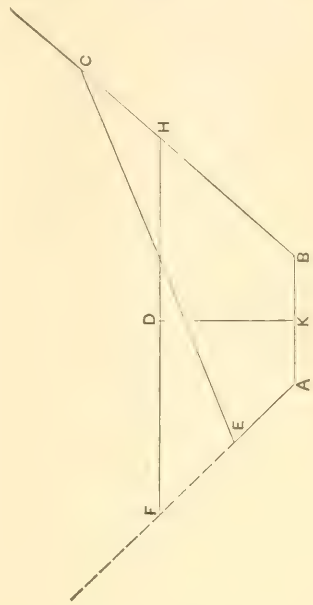
There are many cases on record where men have had to do a certain amount of work in a certain amount of time, the time being regulated by the provisions on hand and the means of transport. Under these circumstances it is often best to run the center line in at once, without going to apex. There are other reasons. If the timber be extra heavy, much time will be lost in chopping that may be saved by doing all this after the line is cleared and the first marks burnt and obliterated.

By taking frequent offsets to the trial line, and having a tracing of the work as laid down in his pocket, the engineer can, by careful attention to simple American rules, keep his line in position (provided he does not make angular errors) without running to apex.

If he suspects an error let him take an observation at once.

Passing on to that part of the author's paper where he treats of the method of calculating quantities from cross sections for construction, it is noticeable that he omits the calculation of quantities for a contract estimate altogether.

As there is often little time to spare over this kind of work, I will try to describe a method of estimating excavation of cuttings and cubes of embankments, introduced by me on the Intercolonial Railway in 1869, and on the Canada Pacific Railway in 1874. It is merely a modification of the method set forth by Mr. I. C. Trautwine in his earthwork tables, depending on the projection of a supposed level surface line, whose vertical ordinates, from grade to new or supposed surface, would produce the same quantities found by calculation from dimensions on sidelong ground. Having plotted the necessary preliminary cross sections from field notes, these are to be equalized by parallel rules to equivalent area under level surface as follows:



Let ABCE be a cross section of a cutting; produce the slope EA indefinitely; assume any point F by guess, a little over the center; lay the parallel ruler from C to F, move to E and mark H—join FH.

If now the line FH be horizontal, or even nearly so, DK will be the proper height to transfer to the profile at the point where prism is situated. Having so equalized all the cross sections and produced a new surface line with supposed level cross section, the quantities may be taken from tables.

If FH be not nearly horizontal, assume a new point F and repeat the process. If the surface line itself be crooked, proceed, first, by rules for equalizing a crooked fence, and afterwards as above directed.

Using this equalized surface line with a set of diagrams made for the particular bases in use, to show the number of feet in length for each successive yard in depth that it takes to make 100 cubic

yards, the quantities may then be taken from the profile by measurement and inspection with a speed and accuracy incredible to those who have not seen it done.

The writer of the last month's paper refers to ditching. I may say of this class of work that the assistant engineer, who can keep an orderly record of borrow ditching, that is cut and re-cut at all manner of irregular distances, shapes and odd times, has kept probably the most difficult class of work in order known to engineers, especially if it be in soft ground, liable to changes of form from drainage, pressure, and other causes. It is a mistake to suppose that the heaviest kind of work is the most difficult to manage or to measure. On the contrary, there is no work more easy to keep track of than plain line cuttings and borrow pits in solid ground.

MOLECULAR ELECTRO-MAGNETIC INDUCTION.

By PROF. D. E. HUGHES, F. R. S.

From "English Mechanic and World of Science."

The induction currents balance shows how extremely sensitive it is to the slightest molecular change in the composition of any metal or alloy, and it gives strong evidence of a peculiarity in iron and steel which its magnetic properties alone failed to account for. We could with all non-magnetic metals easily obtain a perfect balance of force by an equivalent piece of the same metal, but in the case of iron, steel and nickel it was with extreme difficulty that I could obtain a near approach to a perfect zero. Two pieces of iron cut off the same bar or wire, possessing the same magnetic moment, never gave identical results; the difficulty consisted, that notwithstanding each bar or wire could be easily made to produce the same inductive reaction, the time during which this reaction took place varied in each bar; and although I could easily change its balancing power as regards inductive force by a change in the mass of the metal, by heat or magnetism, the zero obtained was never equal to that obtained from copper or silver. This led me to suppose the existence of a peculiarity in magnetic metals which could not be accounted for except upon the hypothesis that there was a cause, then unknown, to produce the invariable effect.

In order to fully understand the mode of experiments, as well as the results obtained, I will first describe the apparatus employed.

The electro-magnetic induction balance consists—1st, of an instrument for producing the new induction current; 2nd, sonometer or balancing coils; 3rd, rheotome and battery; 4th, telephone.

The essential portion of this new balance is that wherein a coil is so arranged that a wire of iron or copper can pass freely through and forming its axis. The iron or copper wire rests upon two supports 20 centims. apart; at one of these the wire is firmly clamped by two binding screws; the opposite end of the wire turns freely on its support, the wire being 22 centims. long, having 2 centims. projection beyond the support, in order to fasten upon it a key or arm, which shall serve as a pointer upon a circle giving the degrees of torsion which the wire receives from turning this pointer. A binding screw allows us to fasten the pointer at any degree, and thus preserve the required stress the time required. The exterior diameter of the coil is $5\frac{1}{2}$ centims., having an interior vacant circular space of $3\frac{1}{2}$ centims., its width is 2 centims.; upon this is wound 200 meters of No. 32 silk-covered copper wire. This coil is fastened to a small board, so arranged that it can be turned through any desired angle in relation to the iron wire which passes through its center, and it can also be moved to any portion of the 20 centims. of wire, in order that different portions of the same wire may be tested for a similar stress. The whole of this instrument, as far as possible, should be constructed of wood, in order to avoid, as far as possible, all disturbing inductive influences of the coil.

The iron wire at its fixed end is joined or makes contact with a copper wire, which returns to the front part of the dial under its board and parallel to its coil, thus forming a loop; the free end of the iron wire is joined to one pole of the battery, the copper wire under the board is joined to the rheotome and thence to the battery.

The coil is joined to the telephone; but, as in every instance we can either pass the battery through the wire, listening to its inductive effects upon the wire, or the reverse of this, I prefer, generally, in order to have no voltaic current passing through the wire, to join the iron wire and its loop direct to the telephone, passing the voltaic current through the coil.

In order to balance, measure, and know the direction of the new induction currents by means of a switching key, the sonometer I described to the Royal Society is brought into the circuit. The two exterior coils of the sonometer are then in the circuit of the battery, and of the coil upon the board containing the iron wire or stress bridge. The interior or movable coil of the sonometer is then in the circuit of the iron wire and telephone. Instead of the sonometer constructed as described at the place cited, another form is preferred. This consists of two coils only, one of which is smaller and turns freely in the center of the outside coil. The exterior coil being stationary, the center coil turns upon an axle by means of a long (20 centims.) arm or pointer, the point of which moves over a graduated arc or circle. Whenever the axis of the interior coil is perpendicular to the exterior coil no induction takes place, and we have a perfect zero; by turning the interior coil through any degree we have a current proportional to this angle, and in the direction in which it is turned. As this instrument obeys all the well-known laws for galvanometers, the readings and evaluations are easy and rapid.

If the coil upon the stress bridge is perpendicular to the iron wire, and if the sonometer coil is at zero, no currents or sounds in the telephone will be perceived, but the slightest current in the iron wire produced by torsion will at once be heard; and by moving the sonometer coil in a direction corresponding to the current a new zero will be obtained, which will not only balance the force of the new current, but indicate its value. A perfect zero, however, will not result with the powerful currents obtained by the torsion of 2 milims. diameter iron wire; we then require special arrangements of the sonometer which are too complicated to describe here.

The rheotome is a clockwork, having a rapid revolving wheel which gives interruptions of currents in fixed cadences, in order to have equal intervals of sounds and silence. I employ four bichromate cells or eight Daniell's elements, and they are joined through this rheotome to the coil on the stress bridge, as I have already described.

The magnetic properties of iron, steel, nickel, and cobalt have been so searchingly investigated by ancient as well as by modern scientific authors, that there seems little left to be known as regards their molar magnetism. I use the word molar here simply to distinguish or separate the idea of a magnetic bar of iron or steel magnetized longitudinally or transversely from the polarized molecules which are supposed to produce its external magnetic effects.

Molar magnetism, whilst having the power of inducing an electric current in an adjacent wire, provided that either has motion or a change in its magnetic force, as shown by Faraday in 1832, has no power of inducing an electric current upon itself or its own molar constituent, either by motion or change of its magnetic moment. Molecular magnetism (the results of which, I believe, I have been the first to obtain) has no, or very feeble, power of inducing either magnetism or an electric current in an adjacent wire, but it possesses the remarkable power of strongly reacting upon its own molar wire, inducing (comparatively with its length) powerful electric currents, in a circuit of which this forms a part.

In some cases, as will be shown, we may have both cases existing in the same wire; this occurs when the wire is under the influence of stress, either external or internal; it would have been most difficult to separate these two, as it was in my experiments with the induction balance, without the aid of my new method.

Ampere's theory supposes a molecular

magnetism or polarity, and that molar magnetism would be produced when the molar magnetism became symmetrical; and his theory, I believe, is fully capable of explaining the effects I have obtained, if we admit that we can rotate the paths of the polarized molecules by an elastic torsion. Matteucci made use of an inducing and secondary coil in the year 1847, by means of which he observed that mechanical strains increased or depressed the magnetism of a bar inside this coil. Wertheim published in the *Comptes rendus*, 1852, some results similar to Matteucci; but in the *Annales de Chimie et de Physique*, 1857, he published a long series of most remarkable experiments, in which he clearly proves the influence of torsion upon the increment or decrement of a magnetical wire. Villari showed increase or diminution of magnetism by longitudinal pull according as the magnetizing force is less or greater than a certain critical value. Wiedermann, in his remarkable work, "Galvanismus," says that an iron wire, through which an electric current is flowing, becomes magnetized by twisting the wire. This effect I have repeated, but found the effects very weak, no doubt due to the weak battery I use, viz., four quart bichromate cells. Sir W. Thomson shows clearly in his remarkable contribution to the *Phil. Trans. Roy. Soc.*, entitled "Effects of Stress on the Magnetization of Iron, Nickel and Cobalt," the critical value of the magnetization of these metals under varying stress, and also explains the longitudinal magnetism produced by Weidermann as due to the outside molar twist of the wire, making the current pass as in a spiral round a fixed center. Sir William Thomson also shows clearly the effects of longitudinal as well as transversal strains, both as regards its molar magnetism and its electric conductivity. My own researches convince me that we have in molecular magnetism a distinct and separate form of magnetism from that when we develop, or render evident, longitudinal or transversal magnetism, which I have before defined as molar.

Molecular magnetism is developed by any slight strain or twist other than longitudinal, and it is only developed by an elastic twist; for, however much we may twist a wire, provided that its fibers are not separated, we shall only have the result due to the reaction of its remaining elasticity. If we place an iron wire, say 20 centims. long, 1 millim. diameter, in the axis of the coil of the electro-magnetic balance, and if this wire is joined, as described, to the telephone, we find that on passing an electric current through the inducing coil no current is perceptible upon the iron wire; but if we give a very slight twist to this wire at its free end—one-eighteenth of a turn, or 20°—we at once hear, clear and comparatively loud, the currents passing the coil: and although we only gave a slight elastic twist of 20° of a whole turn, and this spread over 20 centims. in length, making an extremely slight molar spiral, yet the effects are more powerful than if, using a wire free from stress, we turned the whole coil 40°. The current obtained when we turn the coil, as just mentioned, is secondary, and with the coil at any angle any current produced by its action, either on a copper, silver, iron or steel wire; in fact, it is simply Faraday's discovery, but the current from an elastic twist is no longer secondary under the same conditions, but tertiary, as I shall demonstrate later on. The current passing through the coil cannot induce a current upon a wire perpendicular to itself, but the molecules of the outside of the wire, being under a greater elastic stress than the wire itself, they are no longer perpendicular to the center of the wire, and consequently they react upon this wire as separate magnets would upon an adjacent wire. It might here be readily supposed that a wire having several twists, or a fixed molar twist of a given amount, would produce similar effects. It, however, does not, for in most cases the current obtained from the molar twists are in a contrary direction to that of the elastic torsion. Thus, if I place an iron wire under a right-handed elastic twist of 20°, I find a positive current of 50° sonometer; but if I continue this twist so that the index makes one or several entire revolutions, thus giving a permanent molar twist of several turns, I find upon leaving the index free from any elastic torsion, that I have a permanent current of 10°, but it is no longer positive, but negative, requiring that we should give an elastic torsion in the pre-

vious direction, in order to produce a positive current. Here a permanent elastic torsion of the molecules is set up in the contrary direction to its molar twist, and we have a negative current, overpowering any positive current which should have been due to the twisted wire.

The following table shows the influence of a permanent twist, and that the current obtained when the wire was freed from its elastic torsion was in opposition to that which should have been produced by the permanent twist. Thus, a well-softened iron wire, 1 millim. in diameter, giving 60° positive current for a right-handed elastic torsion of 20°, gave after 1.80° permanent torsion a negative current of 10°.

1 complete permanent torsion (right-handed negative)	10
2 " " "	15
3 " " "	15
4 " " "	16
5 " " "	12
6 " " "	10
7 " " "	5
8 " " "	4
9 " " "	3
10 " " "	3

At this point the fibers of a soft wire commence to separate, and we have no longer a complete wire, but a helix of separate wires upon a central structure.

If now, instead of passing the current through the coil, I pass it through the wire, and place the telephone upon the coil circuit, I find that I obtain equally as strong tertiary currents upon the coil as in the previous case, although in the first case there was produced longitudinal electro-magnetism in the perpendicular wire by the action of the coil; but in the latter case none of the most feeble electro-magnetism was produced, yet in these two distinct cases we have a powerful current produced not only upon its own wire, but upon the coil, thus proving that the effects are equally produced both on the wire and coil.

If we desire, however, in these reversible effects to produce in both cases the same electromotive force, we must remember that the tertiary current, when reacting upon its own short wire, produces a current of great quantity, the coil one of comparative higher intensity. We can, however, easily convert the great quantity of the wire into one of higher tension, by passing it through the primary of a small induction coil whose resistance is not greater than one ohm. We can then join our telephone, which may be one of a high resistance, to the secondary of this induction coil, and by this means, and without changing the resistance of the telephone, receive the same amount of force, either from the iron wire or the coil.

Finding that iron, steel, and all magnetic metals produce a current by a slight twist, if now we replace this wire by one of copper or non-magnetic metals we have no current whatever by an elastic twist, and no effects, except when the wire itself is twisted spirally in helix, and whatever current we may obtain from copper, &c., no matter if from its being in spiral or from not being perpendicular to the axis of the coils, the currents obtained will be invariably secondary and not tertiary. If we replace the copper by an iron wire, and give it a certain fixed torsion, not passing its limit of elasticity, we find that no increase or decrease takes place by long action or time of being under strain. Thus, a wire which gave a sonometric force of 50° at the first observation, remained perfectly constant for several days until it was again brought to zero by taking off the strain it had received. Thus, we may consider that as long as the wire preserves its elasticity, exactly in the same ratio will it preserve the molecular character of its magnetism.

It is not necessary to use a wire to produce these effects; still more powerful currents are generated in bars, ribbons, or sheets of iron; thus, no matter what external form it may posses, it still produces all the effects I have described.

It requires a great many permanent twists in a wire to be able to see any effect from these twists; but if we give to a wire, 1 millim. diameter, 40 whole turns (or until its fibers become separated) we find some new effects; we find a small current of 10° in the same direction as its molar twist, and on giving a slight twist (20°) the sonometric value of the sound obtained is 80°, instead of 50°, the real value of a similar untwisted wire; but its explanation will be found by twisting the wire in a contrary direction to its molar twist. We can now approach the zero but never produce a current in the contrary direction, owing

to the fact that by the spiral direction, due to the fibrous molar turns, the neutral position of its molecules are no longer parallel with its wire, but parallel with its molar twist, consequently an elastic strain in the latter case can only bring the molecules parallel with its wire, producing no current, and in the first case the angle at which the reaction takes place is greater than before, consequently the increased value of its current.

The measurements of electric force mentioned in this paper are all sonometric on an arbitrary scale. Their absolute value has not yet been obtained, as we do not, at our present stage, require any except comparative measures. Thus, if each wire is of 1 millim. diameter and 20 centims. long, all render the same stress in the axis of ts coil. I find that the following are he sonometric degrees of value:

Soft iron........ ...	60°	Tertiary current.
Hard drum iron....	50°	" "
Soft steel..........	45°	" "
Hard tempered steel	10°	" "
Copper, silver, &c..	—0°	
Copper helix, I centim. diameter, 20 turns in 20 centims	45	Secondary currents.
Iron, spiral, ditto...	45°	" "
Steel...............	45	" "

The tertiary current increases with the diameter of the wire, the ratio of which has not yet been determined; thus, an ordinary hard iron wire of one millim. diameter giving 50°, one of two millims. diameter gave 100°; and the maximum of force obtained by any degree of torsion is at or near its limit of elasticity, as if in same time we also pass this point, producing a permanent twist, the current decreases, as I have already shown in the case of a permanent twist. Thus, the critical point of one millim. hard iron wire was 20° of torsion, but in hard steel it was 45°.

Longitudinal strains do not produce any current whatever, but a very slight twist to a wire, under a longitudinal strain, produces its maximum effects; thus, 20° of torsion being the critical point of iron wire, the same wire, under longitudinal strain, required but from 10° to 15°. It is very difficult, however, to produce a perfect longitudinal strain alone. I have, therefore, only been able to try the effect of longitudinal strain on fine wires, not larger than one millim. in diameter, but as in all cases no effect whatever was produced by longitudinal strain alone, I believe none will be found if absolutely free from torsion. The molecules in a longitudinal strain are equally under an elastic strain as in torsion, but the path of their motion is now parallel with its wire, or the zero of electric inductive effect, but the compound strain, composed of longitudinal and transverse, react upon each other, producing the increased effect due to the compound strain.

The sonometer is not only useful for showing the direction of the current and measuring it by the zero method, but it also shows at once if the current measured is secondary or tertiary. If the current is secondary its period of action coincides with that of the sonometer, and a perfect balance, or zero of sound, is at once obtained, and its value in sonometric degrees given; but if the current is tertiary, no zero is possible, and if the value of the tertiary is 60°, we find 60° the nearest approach to zero possible. But by the aid of separate induction coils to convert the secondary into a tertiary, a perfect zero can be obtained if the time of action and its force correspond to that which we wish to measure.

If I place a copper wire in the balance, and turn the coils at an angle of 45°, I obtain a current which the sonometer gives a perfect zero at 50°, proving, as already said, that it is secondary. If I now replace the copper by an iron wire, the coil remaining at 45°, I have again exactly the same value for the iron as copper, viz., 50°, and in both cases secondary. Now, it is evident that in the case of the iron wire there was produced at each passage of the current a strong electro-magnet; but this longitudinal magnetism did not either change the character of the current or its value in force.

A most beautiful demonstration of the fact that longitudinal magnetism produces no current, but that molecular magnetism can act equally as well, no matter the direction of the longitudinal magnetism, consists in forming an iron wire in a loop, or taking two parallel but separate wires, joined electrically at their fixed ends, the free ends being each connected with the circuit, so that the cur-

rent generated must pass up one wire and down the adjacent one. On testing this loop, and if there are no internal strains, complete silence or absence of current will be found. Now, giving a slight torsion to one of these wires in a given direction, we find, say, 50° positive; twisting the parallel wire in a similar direction produces a perfect zero, thus the current of the second must have balanced the positive of the first. If, instead of twisting it in similar directions, we twist it in the contrary direction, the sounds are increased in value from 50° positive to 100° positive, showing, in this latter case, not only a twofold increase of force, but that the currents in the iron wires traveled up one wire and down the other, notwithstanding that both were strongly magnetic by the influence of the coil in one direction, and this experiment also proves that its molar magnetism had no effect, as the currents are equally strong in both directions, and both wires can double or efface the currents produced in each. If, instead of two wires, we take four, we can produce a zero, or a current of 200°, and with twenty wires we have a force of 1,000°, or an electromotive force of two volts. We have here a means of multiplying the effects by giving an elastic torsion to each separate wire, and joining them electrically in tension. If loops are formed of one iron and one copper wire, we can obtain both currents from the iron wire, positive and negative, but none from the copper; its *rôle* is simply that of a conductor upon which torsion has no effect.

I have already mentioned that internal strains will give out tertiary currents, without any external elastic strain being put on. In the case of iron wire, these disappear by a few twists in both directions, but in flat bars or forged iron, they are more permanent; evidently, portions of these bars have an elastic strain, whilst other portions are free, for I find a difference at every inch tested; the instrument, however, is so admirably sensitive, and able to point out not only the strain, but its direction, that I have no doubt its application to large forged pieces, such as shafts or cannon, would bring out most interesting results, besides its practical utility; great care is therefore necessary in these experiments that we have a wire free from internal strains, or that we know their value.

Magnetizing the iron wire by a large steel permanent magnet has no effect whatever. A hard steel wire thus placed becomes strongly magnetic, but no current is generated, nor has it any influence upon the results obtained from molecular movement, as in elastic torsion. A flat wide iron or steel bar shows this better than iron wire, as we can here produce transversal, instead of longitudinal, but neither shows any trace of the currents produced by molecular magnetism. I have made many experiments with wires and bars thus magnetized; but as the effect in every case was negative when freed from experimental errors, I will not mention them; but there is one very interesting proof which the instrument gives, that longitudinal magnetism first passes through its molecular condition before and during the discharge, or recomposition of its magnetism. For this purpose, using no battery, I join the rheotome and telephone to the coil, the wire having no exterior circuit. If I strongly magnetize the two ends of the wire, I find by rapidly moving the coil, that there is a Faradaic induction of 50° at both poles, but very little or none at the center of the wire; now fixing the coil at the central or neutral point of the wire, and listening intently, no sounds are heard; but the instant I give a slight elastic torsion to the free pole, a rush of electric tertiary induction is heard, whose value is 40°. Again, testing this wire by moving the coil, I find only a remaining magnetism of 10, and upon repeating the experiment of elastic torsion, I find a tertiary of 5; thus can we go on gradually discharging the wire, but its discharge will be found to be a recomposition, and that it first passed through the stage I have mentioned.

Heat has a very great effect upon molecular magnetic effects. On iron it increases the current, but in steel the current is diminished. For experimenting on iron wire, which gave a tertiary current of 50° positive (with a torsion of 20°), upon the application of the flame of a spirit lamp, the force rapidly increases (care being taken not to approach red heat) until the force is doubled, or 100 positive. The same effects were obtained

in either direction, and were not due to a molar twist or thermo-current, as if care had been taken to put on not more than 10° of torsion, the wire came back to zero at once on removal of the torsion. Hard-tempered steel, whose value was 10° whilst cold, with a torsion of 45°, became only 1° when heated, but returned (if not too much heated) to 8° when cold. I very much doubted this experiment at first, but on repeating the experiment with steel several times, I found that on heating it, I had softened the extreme hard (yellow) temper to that of the well-known blue temper. Now, at blue temper, hot, the value of steel was but 1° to 2°, whilst soft iron of a similar size gave 50° of force cold, and 100° at red heat. Now, as I have already shown that the effects I have described depend on molecular elasticity, it proves at least, as far as iron and steel are concerned, that a comparatively perfect elastic body, such as tempered steel, has but a slight molecular elasticity, and that heat reduces it, but that soft iron, having but little molar elasticity, has a molecular elasticity of a very high degree, which is increased by heat.

The objects of the present paper being to bring the experimental facts before the notice of the Royal Society, and not to give a theoretical solution of the phenomena, I will simply add, that if we assume with Poisson, that the paths of the molecules of iron are circles, and that they become ellipses by compression or strain, and also that they are capable of being polarized, it would sufficiently explain the new effects.

Joule has shown that an iron bar is longer and narrower during magnetization than before, and in the case of the transverse strain, the exterior portions of the wire are under a far greater strain than those near the center, and as the polarized ellipses are at an angle with the molecules of the central portions of the wire, its polarization reacts upon them, producing the comparatively strong electric currents I have described.

STEEL.*

By J. RILEY, General Manager to the Steel Company of Scotland.

From "Iron."

I do not think any justification is necessary for bringing this subject before you; but were such the case, I think it would be found in the increasing magnitude of the number and extent of the works engaged in the manufacture of steel in this district, and in the large and increasing measure of the use of that material in our midst, more especially in connection with shipbuilding and engineering. With that spirit of enterprise and enlightened progress which is the characteristic of those engaged in these pursuits on the Clyde, the metal "mild steel"—which has been called the metal of the future—had not been long under the notice of the public ere they commenced its use, and the results of their extended experience of its many good qualities has been so satisfactory that, being able to recommend it to their clients, the demand for this class of steel has increased constantly and rapidly—indeed, at a rate which has heavily taxed the powers of those engaged in its manufacture. I shall have occasion later to return to this, and at present would only say that, only about three years ago, the Steel Company of Scotland—and at that time the only firm in Scotland engaged largely in the manufacture of steel—found that less than 100 tons of "mild steel" produced weekly enabled them to meet all demands upon them; whereas at present they have had difficulty in executing all calls upon them when producing not less than 1400 tons weekly, and their efforts have been supplemented by those of one or two other firms in Scotland, who have been induced to commence this manufacture by the largeness of the present and prospective demand. It does indeed seem probable that in a very short time Lanarkshire

* Delivered at the Naval and Marine Engineering Exhibition, Glasgow.

will be the foremost of the "mild steel" making districts in Great Britain—if not of the world; for I take it that the works now complete and in progress will shortly have a producing power of not far short of 4000 tons weekly of "mild steel" alone. In their total-producing capacity they will probably have a yield of near 6000 tons of ingots, requiring about 4500 to 5000 tons of hematite pig iron weekly in its production. Up till recently the pig iron used in this manufacture was brought from England; now, however, many of the makers of pig iron in this district have turned their attention to making hematite iron; and I expect that the whole of our requirements will shortly be met at home, and thus the superabundant make of ordinary Scotch pig iron will be largely reduced.

I doubt not that many of the outside public have been surprised and perplexed at the idea of steel being used in the construction of ships and boilers, the name "steel" being associated in their minds with sharp cutting instruments of hard and possibly brittle character. In the same way, but of course not to the same extent, many who have been engaged in the use of iron for a long period and thoroughly understand its characteristics, but who have had no practical acquaintance with the newer classes of "steel," have no doubt had many misgivings as to the propriety of its use in these directions, and also of their own ability to deal successfully with it, should they be required to use it in their ordinary occupations. These ideas have contributed largely to that disinclination to adopt the "new material" with which steelmakers have been so long and so successfully contending. The application of the term "steel" to the newer classes of this metal was indeed unfortunate, so far as makers were concerned, and has contributed not a little to the many difficulties they have experienced in the conduct of their business. Even in the minds of experts there has been something approaching to a confusion of ideas regarding these metals through the use of this term "steel," and some efforts have been made to get over the difficulty by a division into classes, whereby the milder or softer should be called "ingot iron," or homogeneous metal, while the harder retained the older designation of steel, but difficulties which I need not here enumerate have prevented the general adoption of this proposal. Now the definition is pretty generally accepted, that steel is an alloy of iron which is cast while in a fluid state into a malleable ingot. Yet this does not cover some of the steels to which I shall have to refer.

The history of steel is of great and increasing interest whether we consider the various processes by which it has been and is produced, the inventors of these different processes, with the vicissitudes of fortune through which both have passed, or its application to the various requirements of a constantly advancing civilization. I do not, however, propose to refer in more than an incidental manner to some of these matters, but I trust that the facts I may lay before you may be found of sufficient interest to warrant their introduction. Steel, as I have said, is an alloy of iron, and this principally with carbon, and the aim of the manufacturer is to obtain the alloy with such proportions of each as shall best fit it for the purpose for which it is intended. In order to accomplish this he may adopt some one of the following methods: Having ore of sufficient purity he may reduce it and obtain malleable iron or steel, by one or other of the direct processes as they are called; thus dispensing with the usual intermediate stages, by which the ore is first reduced in the blast furnaces and pig iron produced, to be afterwards, by puddling, &c., made into bar or wrought iron; or, taking the wrought iron so produced, and which may contain too little carbon for his purpose, he may seek by various means to increase its proportion to the iron; or, on the other hand, having crude or pig iron, which contains a varying amount of carbon, but in all cases too much to admit of its being wrought—that is, hammered, rolled or welded—he may seek to reduce the proportion of carbon present either by removing some of it by oxidation, or by diluting it by increasing the proportion of the iron. All the various processes for producing steel, whether of ancient or modern times, are based on one or other of these principles, or a combination of them. It is my purpose to-night

to describe these various processes, and I trust I may be able to do so in an intelligible manner. The most primitive method of making steel of which we have any knowledge, is that practiced by the natives of India, and some other countries where the ore is reduced in bloomeries, as they are sometimes termed, and of which the Catalan process may be taken as an illustration. Only the richest and purest ores are used. These are heated in contact with carbon—*i. e.*, charcoal—until reduction takes place, when it is only necessary to remove the spongy mass, and, by hammering, to bring about the aggregation of the particles. The iron thus obtained is broken into small pieces and selected. In making the celebrated Wootz steel, the natives of India pack small pieces of this malleable iron with wood in crucibles, which are then heaped over with some green leaves and clay. About two dozen of these crucibles are packed in one furnace; they are covered over with fuel, and blast is applied for about two and a half hours, when the operation is terminated. The crucibles are broken when cold, and the small cakes of steel removed.

The fact that the production of wrought iron or steel, direct from the ore, has excited so much interest in the minds of metallurgists is not to be wondered at when the cost of reduction by means of the blast furnace, and the subsequent necessary operations are borne in mind. Hence there have been many proposals for accomplishing this desirable end, but as few of them have passed the experimental stage, and as none have yet been commercially successful on a large scale, I do not think it necessary to take up your time with a description of any of them. I would simply indicate that the processes of Chenot, of Blair, and of Siemens, appear to have come nearest achieving the object aimed at. In dealing with wrought iron by what is known as the "cementation process," bars are rolled or hammered to the required section. They are then cut to the proper length, and charged into furnaces known as converting furnaces. The pots or troughs on the beds of these furnaces, which are made of refractory materials, are strewed with charcoal powder to the thickness of one or two inches. A layer of bars is placed on this bed, and covered with charcoal, on which are again laid alternate layers of bars and charcoal until the troughs are nearly filled, when they are covered several inches thick with charcoal, and afterwards with what is called "wheelswarf," produced at the grinding stones. All the apertures of the furnace are then closed, and the fires lighted on the grates. In a few days the furnace attains its full heat, at which it is kept for several days according to the degree of hardness required, depending upon the amount of carbon combined with the iron. The progress made in carburization is tested from time to time after the sixth day by drawing bars from the troughs. When these prove satisfactory, the fire is heaped up with small coal, and then allowed to die out. The furnaces are of different capacities, varying from 15 to 30 tons; and this cementation process, as it is called, may be said to occupy about three weeks. The bar steel produced is known as "blistered steel," because when discharged from the furnace the bars are found partially covered by small raised portions of the metal, resembling blisters. On breaking the bars across, the texture is seen to be no longer fibrous, but granular or crystalline; the color is white, and the crystals are large in proportion to the amount of carbon absorbed. "Shear steel" is the product from these bars of blistered steel, broken into lengths, bundled, or made into faggots, which are rolled or hammered out at welding heat to the form required.

This operation is repeated until a sufficiently uniform texture is obtained. All the loose parts and seams of the blistered steel are closed, and it is now capable of being highly polished; it is also more malleable, and can be forged into shears, edge-tools, and cutting instruments. The value of the steel increases with the amount of hammering which it receives, and the terms "double shear," "single shear," &c., express the amount of doubling and welding which the bars have undergone. Again, steel is made from wrought iron by fusion with carbonaceous matter, as in the case of the Indian Wootz process, previously described, and by a process introduced by Mushet, which consists in melting malle-

able scrap iron with charcoal and oxide of iron in crucibles.

Crucible steel is made in two classes of furnaces, with which it may be as well that you should become acquainted at this point. The first and oldest form is that known as the coke or melting-hole furnace. The furnace, or melting hole, is a small square or oblong chamber, about three feet deep, and from one and a half to two feet square, lined with refractory material, such as firebrick, or the siliceous stone known as gannister. The top of the furnace is placed level with the floor of the casting house, the grate bars and ashpit being accessible from below through a vaulted cellar or cave. The cover of the furnace is a square of firebrick, set in an iron frame, with a projecting handle. There is a short flue near the top of the furnace communicating with the stack, which is about 40 feet high, in order to command a strong draught. Several furnaces are usually arranged in longitudinal series on opposite sides of the casting house, leaving the center of the floor clear for placing the moulds. Usually two pots or crucibles are placed in a furnace. They stand upon cylindrical discs of fire-bricks, resting on the grate bars. Previously to being used they require to be gradually heated to redness in an open fire or annealing grate, which is done by placing them in batches of twenty, bottom upwards, together with their covers, upon a bed of red-hot coal in the grate; the intermediate space is then filled with coke, and the fire is urged until the necessary heat has been obtained. The pots are then removed to the melting furnaces, and fixed in position on the stand. The fires are replenished with coke, and as soon as they have been brought up to a strong heat, which takes place in about twenty minutes, the charge, properly assorted and broken into small pieces, is introduced through a wrought-iron funnel; after which the cover is placed on the pot, and the full heat of the furnace is given for three and a half hours; during which time fresh fuel is added every three-quarters of an hour. When the fusion is complete, which is ascertained by removing the cover, and searching the contents of the crucible with a pointed rod, the crucible is cleared from adherent slaggy masses by stirring below the grate, and is then lifted out by the furnace men with a suitable pair of tongs. The ingot mould, made of cast iron, is blackened or coated by various means, and the contents of the crucible, after being allowed to cool for a short time, are then poured into the mould, and its mouth is covered with a plug of cast iron or a shovelfull of sand, in order to prevent the top of the ingot becoming spongy by the escape of gases before solidification.

The crucible being cleaned is then returned to the furnace for a second melting. The charge is somewhat reduced, because it is found that the crucibles are reduced in strength at the line of the surface of the previous charge, where a cutting action has taken place by the slag from the fluxes employed; consequently, the consumption of coke and the time of fusion are both reduced in proportion. The furnace is allowed to cool after from three to five meltings have been made, as there is no advantage to be gained by keeping it constantly heated, owing to the corrosion of the lining bricks, produced by the very high temperature, whereby the capacity and power of consuming fuel is increased, without a corresponding increase in the amount of steel melted. I have thought it best in this connection to give you a description of the Siemens crucible furnace, which depends for its great advantages over the common furnace, or the application of the regenerative system and the use of gaseous fuel, although I have not yet brought either of these under your notice. This furnace is thus described by its inventor: "In the application of the regenerative system to the fusion of steel in closed pots or crucibles, the melting chamber, containing generally twenty-four pots, is constructed in the form of a long trench, 3 feet 6 inches wide at the bottom, and gathered in to under 2 feet at the top. The sides of the melting chamber are arched, both horizontally and vertically, to keep them from sinking together in working, and the work is strengthened by cross-walls at intervals. The pots are set in a double row along the center of the melting chamber, and the flame passes from side to side, the gas and air from the regenerators being introduced alternately from one side, and from the other, oppo-

site to each pair of pots. The melting chamber is closed above by loose fire-brick covers, which are drawn partly off in succession by means of a lever suspended from a pulley above the furnace, when the pots are to be charged or drawn out. The pots stand in a bed of finely-ground coal dust, resting on iron plates. The coke dust burns away only very slowly if it is made of hard coke and finely ground; and it presents the great advantage of remaining always in the form of a loose, dry powder, in which the pots stand firmly, while every other material that I have tried either softens in the intense heat, or sets, after a time, into a hard, uneven mass, in which the pots do not stand well. The process of melting carried out in this form of gas furnace is the same in all respects as that in the small air furnaces, or melting holes fired with coke, which are commonly employed; but a great saving is effected in the cost of fuel, and in the number of crucibles required. The ordinary consumption of hard coke is between three and four tons per ton of steel fused; while in the gas furnaces the same work may be done by the expenditure of 15 to 20 cwt. of common coal slack, the cost being, say, 5 per cent. against 75 per cent. per ton of melted steel."

The crucibles used in both the furnaces described are made of mixtures of different kinds of fire clay, with a certain proportion of ground potsherds and coke dust. The usual size is from 16 to 18 inches in height, and from 5 to 7 inches diameter at the mouth, with a slight belly at about two-thirds of the height from the bottom; the capacity varies from 35 to 80 lbs. Plumbago pots are now sometimes used, and found to be of advantage in different ways. When any large masses of cast steel are required, the contents of all the crucibles are either poured into a foundry ladle before filling the mould, or the pouring is so arranged that, by bringing up relays of fresh pots, a constant stream may be kept up without intermission. Such an operation is one of great interest, and requires careful preparation and organization so perfect, that hundreds of crucibles must be ready to be taken out of the furnaces in quick succession, and their contents poured into the common receptacles. The finest qualities of crucible cast steel are made by melting cement steel, made from the finest materials, such as the best brands of Swedish iron. The celebrated Huntzman steel is thus prepared; and it must be understood that the quality of the resulting steel depends, in the largest measure, upon the most careful assorting of the materials charged, which is done by workmen skilled in judging of the blistered steel, &c., to be used.

We come now to consider the different methods adopted for producing steel from crude or pig iron. What are known as finery furnaces have been largely used on the Continent for the production of what is known as "natural steel." They are all pretty much of the same type, but vary somewhat in form and dimensions. If you will kindly bear in mind the form of the Catalan forge, during the following description of the process, it may help you to a clearer realization of the operations. There is a tuyere blowing into the metal on an open fire, only the blast is more powerful than in the more primitive furnace. This process was formerly practiced, to a considerable extent, in Styria, Westphalia, and other parts of Europe, but has been rapidly superseded by more improved processes. Bauerman thus describes the process as conducted in Styria: "The first portion of the charge, weighing 120 lbs., is melted down with a small quantity of cinder, the latter being strewed over the coals, the reheating of the blooms from the former operation, about ten or twelve in all, going on at the same time. When only two blooms are left, a further addition of pig iron is made to the extent of from 30 to 60 lbs., and the blowing is continued until the hearth is filled to within one or two inches of the tuyere. The fire is then allowed to go down quickly, the slag is tapped through a hole in the front plate into a trough filled with water, and the lump of crude steel remaining on the hearth is allowed to cool, out of contact with the air, by covering it with a shovelfull of moistened cinders. In about a quarter to half an hour, after stopping the blast, the lump is lifted out of the furnace, and is then divided under the hammer into ten or twelve pieces, which are reheated during the firing of the next charge. The bars

drawn under the hammer are hardened by quenching in cold water, and broken in order to test their quality. They are sorted, according to hardness, into several classes, distinguished by special names. The best are known as chisel or tool steel, Noble steel, and crude steel, below which come a variety of steely irons, used for scythe making, wagon-wheel tires, and similar purposes."

What is known as "puddled steel," made in furnaces differing very slightly from ordinary iron-puddling furnaces, was at one time largely produced; but this process also has, like the last-named, been superseded, so that I need not trouble you with a description of it. I believe, however, that it may still be seen in operation at the Birkenhead Forge. I have now to deal with the two processes which have, in recent years, created, and in fact, are still working out, such a great revolution in the iron and steel manufactures of the world. Before the invention and extensive adoption of the Bessemer and Siemens-Martin processes steel was a very costly material to purchase, and was produced in comparatively small quantities for special purposes, which were restricted within very narrow limits. Now, we have works in this kingdom alone equal to a production of something like 1,000,000 tons of Bessemer, and 400,000 tons of Siemens steel per annum; and the use of the products of these processes is becoming every day more extensive and varied. The railways of the world are now largely made of these metals, as are also large and increasing portions of the engines, carriages, and wagons, which run upon them. The same may be said of the ships of the Royal and merchant navies, together with their engines and boilers. Not only in the arts of peace do we find the use of steel largely and rapidly extending, but also in that of war; for not only are rifles made of it, from the barrel to the striker-needle, but likewise in the construction of guns of heavy caliber, the shell to be fired from them, the carriages on which they are placed, the racers or railways on which they are mounted and trained, and even the armor plates of vessels at which they may be fired. Steel is now rapidly taking the place of iron. If, then, it were interesting to you to know something of the older and more limited methods by which steel has been and is still produced, much more important is it that you should have knowledge regarding those more modern and extensive processes by which they are being replaced. Mr. Bessemer startled the metallurgical world, in 1856, by the statement that he had invented a method of manufacturing malleable iron and steel without fuel. In the paper which he read before the Mechanical Section of the British Association at the Cheltenham meeting in that year he proposed to accomplish this by treating liquid pig iron, which had been melted in a cupola or reverberatory furnace, or even been taken direct from the blast furnace, in a special apparatus, by which thin jets of atmospheric air were forced through the liquid metal. No fuel was used or needed in the process, as the temperature was maintained, and even increased, by the combustion of the carbon, and also by the oxidation of part of the iron. Thus, by the oxidation of the carbon, it was so far reduced that the resulting product was either liquid steel or wrought iron.

You will, doubtless, be struck by the modest extent of Mr. Bessemer's first patent. It is simply a modification of the "coke-hole" furnace already described. The crucible is similar, except that provision is made for tapping the metal out into the ingot mould beneath; also that the cover is altered in form and perforated, so that the gases generated may escape. Through the center of the cover a pipe passes down into the fluid metal conducting the air blast, which is forced through holes at its lower extremity into the fluid metal. From such small beginnings, and such simple means have grown the grand and striking operations of to-day, conducted in the imposing apparatus which Mr. Bessemer afterwards designed, and which gave completeness to his invention. The converters are usually worked in pairs, one being repaired or changed, whilst the other is in full use. They are pear-shaped in form, and are of different sizes, some now being able to take a charge of 15 tons weight, although the most common weight of charge is from 7 to 10 tons. They are suspended on trunnions, and provided with machinery, by which they

can be rotated vertically through an angle of 180°. The outer casing is made of wrought iron riveted together; the lining is made of very refractory materials, gannister being mostly used for this purpose, the tuyeres are peforated by parallel holes about $\frac{5}{8}$-inch diameter, and from seven to twelve in number, and through them the blast is forced into the metal, after having passed through one of the trunnions, which is made hollow, into the wind box under the tuyeres. The blast has a pressure of from 20 to 25 lbs. on the square inch. The ladle carriage is arranged so that it can be raised and lowered, as well as made to revolve on its axis, like a railway turn-table; thus it can be lowered to recieve the charge from the converter, then passed out from under the vessel, and afterwards over each ingot mould in succession. The machinery for moving the converters and the ladle carriage is worked by hydraulic power, and is controlled by one man placed at a little distance, where he can clearly discern and govern the whole of the operations, including the admission of blast to the vessels. I hope I have given you an idea of the machinery of the Bessemer pit, and will now proceed to describe to you the manner in which the process may practically be carried into operation, and I do this in the words used by Mr. Bessemer, in a paper read before the Institution of Civil Engineers, in 1865.

"The vessel, having been heated, is brought into a horizontal position, so that it may receive its charge of melted metal without the tuyeres being below the surface. No action can therefore take place until the vessel is made to assume the vertical position. The process is thus, in an instant, brought into full activity, and small though powerful jets of air spring upward through the fluid mass. The air expanding in volume divides itself into globules, or bursts violently upwards, carrying with it some hundredweights of fluid metal, which again fall into the boiling mass below. Every part of the apparatus trembles under the violent agitation thus produced, a roaring flame rushes from the mouth of the vessel, and as the process advances, it changes its violet color to orange, and finally to a voluminous pure white flame. The sparks which at first were large, like ordinary foundry iron, change to small hissing points, and these gradually give way to soft floating specks of blueish light as the state of malleable iron is approached." "Thus, by the mere action of the blast, a temperature is obtained in the largest masses of metal in ten or twelve minutes, that whole days of exposure in the most powerful furnaces would fail to produce." "The changes in the color and volume of the flame, and the kind of sparks thrown off, afford easy methods of judging of the state of the metal. The sound which the metal produces in the suspended vessel affords also a good indication to the workman. Indeed, few processes appeal so strongly to the external. senses. When the desired quantity of air has passed through the metal, the vessel is turned on its axis, and the fluid steel is poured out. It is then received in the casting ladle, which is attached to the arm of an hydraulic crane so as to be brought readily over the moulds. The ladle is provided with a fireclay plug at the bottom, the raising of which, by a suitable lever, allows the fluid steel to descend in a clear vertical stream into the moulds. As soon as the first mould is filled, the plug valve is depressed, and the metal is prevented from flowing until the casting ladle is moved over the next mould when, by raising the plug, the second mould is filled in like manner, and so on until all the moulds are filled. After the discharge of the vessel the process should be repeated without delay, since the temperature of the vessel is greater after the first charge than it was before, and, consequently, it is in a better condition for the process. Thus, by the control of one responsible man, charges of several tons of crude cast iron may be converted into malleable iron, or into steel, in a few minutes, and be cast into ingots of any desired form and weight, suitable for larger shafts, or for rolling into rails, merchant bars, or plates.

Such is the Bessemer process, and it can scarcely be wondered at, that when the inventor first made it public, "his proposition was (to use his own words) almost generally looked upon as a chimera, or, as the mere day dream of an enthusiast, which the quiet, everyday practical man felt bound to disbelieve,"

although the laws on which the whole theory of his invention was based were well known; and hence the process was recognized from the very first by many of the scientific men of the day. The history of Mr. Bessemer's early difficulties, and how they were gradually, one by one, overcome; of how he determined, in spite of the opinions loudly expressed against the process, to pursue an undeviating course, and to remain silent for years under the scepticism of those who predicted its failure, rather than again to bring forward his invention until he had himself practically and commercially worked the process. I say this history is one of deep interest, and calculated to excite within us great sympathy for him in his earlier efforts and failures, as well as admiration of the patience and perseverence he exercised under them, and the powers of mind and fertility of resource manifested throughout. There had been long an idea that steel might be made on the open hearth of a furnace, before Dr. Siemens furnished the means of its accomplishment by the application of the regenerative gas furnace to this end. Of all the plans with this object, that proposed and patented by Heath in 1845, was the first. He conceived that cast steel might be produced by fusing wrought and cast iron together on the open hearth of a reverberatory furnace. The wrought iron was to be placed in a separate part of the furnace between the fluid metal and the chimney, and, having been there heated by the waste heat of the flame, was to be pushed forward into the bath in order to be dissolved. Heath proposed to heat his furnace by jets of gas, fearing the effect of the ashes from a common fire place. This process gave great promise of success, but failed from want of ability to obtain the necessary intensity of heat, and to control sufficiently the action and character of the flame.

I pass by other proposed modes of working to mention that known as the Siemens-Martin process. It is now about twenty years since Dr. Siemens—having, in conjunction with his brother, patented the regenerative gas furnace—first directed his attention to the melting of steel in pots and on the open hearth. His improvements on the ordinary crucible furnace I have already described, but when doing so I passed over the means devised for obtaining the gaseous fuel—a most essential and important part of all his inventions. This is known as the Siemens gas producer, which has been described as follows: "A brick chamber, perhaps 6 feet by 12 feet, and about 10 feet high, has one of its end walls converted into a fire grate, *i. e.*, about half way down it is a solid plate, and for the rest of the distance consists of strong horizontal plate bars, where air enters; the whole being at an inclination such as that which the side of a heap of coals would naturally take. Coals are poured through openings above upon this combination of wall and grate, and being fired at the under surface, they burn at the place where the air enters; but as the layer of coal is from two to three feet thick, various operations go on in those parts of the fuel which cannot burn for want of air. Thus the upper and cooler part of the coal produces a large body of hydro-carbons. The cinders or coke which are not volatilized, approach in descending towards the grate. That part which is nearest the grate burns with the entering air into carbonic acid, and the heat evolved ignites the mass above it; the carbonic acid passing slowly through the ignited carbon becomes converted into carbonic oxide, and mingles in the upper part of the chamber (or gas producer) with the hydro-carbons. The water which is purposely introduced at the bottom of the arrangement, is first vaporized by the heat, and then decomposed by the ignited fuel, and rearranged as hydrogen and carbonic oxide, and only the ashes of the coal are removed as solid matter from the chamber at the bottom of the firebars."

In the lecture which Dr. Siemens recently delivered here, he described an improved form of gas producer which seems to give promise of many useful improvements on the one now in general use, and which I have just referred to. Professor Faraday thus lucidly described the Siemens open-hearth regenerative furnace: "The gas from producers rises up a large vertical tube for 12 or 15 feet; after which it proceeds horizontally for any required distance, and then descends to the heat regenerator, through which it passes before it enters the furnace. A regenerator is a chamber packed with

fire bricks, separated so as to allow of the free passage of air or gas between. There are four placed under a furnace. The gas ascends through one of these chambers, whilst air ascends through the neighboring chamber, and both are conducted through passage outlets at one end of the furnace, where, mingling, they burn, producing the heat due to their chemical action. Passing onward to the other end of the furnace, they—*i. e.*, the combined gases—find precisely similar outlets, down which they pass; and traversing the two remaining generators from above downwards, heat them intensely, especially in the upper part, and so travel on in their cooled state to the shaft or chimney. Now, the passages between the four regenerators and the gas and air, are supplied with valves and deflecting plates, which are like four-way cocks in their action, so that by the use of a lever those regenerators and airways, which were carrying off the expended fuel, can, in a moment, be used for conducting air and gas into the furnace; and those which just before had served to carry air and gas into the furnace, now take the burnt fuel away to the stack. It is to be observed that the intensely heated flame which leaves the furnace for the stack always proceeds downwards through the regenerators, so that the upper part of them is most intensely heated, keeping back, as it does, the intense heat; and so effectual are they in this action, that the gases which enter the stack to be cast into the air are not usually above 300° Fah. of heat. On the other hand, the entering gas and air always pass upwards through the regenerators, so that they attain a temperature equal to a white heat before they meet in the furnace, and then add to the carried heat that due to their mutual chemical action. It is considered that when the furnace is in full order, the heat carried forward to be evolved by the chemical action is about 4,000°, whilst that carried back by the regenerator is about 3,000°, making an intensity of power which, unless moderated on purpose, would fuse furnace and all exposed to its action. Thus the regenerators are alternately heated and cooled by the outgoing and entering gas and air; and the time for alteration is from half an hour to an hour, as observation may indicate. The motive power on the gas is of two kinds; a slight excess of pressure within is kept up from the gas producer to the bottom of the regenerator, to prevent air entering and mingling with the fuel before it is burnt; but from the furnace downwards through the regenerators the advance of the heated medium is governed mainly by the draught in the tall stack or chimney.

As in the case of Sir Henry Bessemer, so again in that of Dr. Siemens, the difficulties and disappointments which attended his efforts to introduce his process and secure its adoption by manufacturers were such as would have daunted and overcome a less resolute spirit; but here, again, there is the same confidence that success is possible, combined with the determination that it shall be achieved, and the necessary powers of mind and of resources to justify both the confidence and determination. The result of his labors is manifest in the high estimation in which his process is now generally held, especially where finer qualities of steel are required for purposes where uniformity and regularity in the product are of vital importance. Dr. Siemens states that, "having been so often disappointed by the indifference of manufacturers and the antagonism of their workmen, I determined in 1865 to erect experimental or 'sample steel works' of my own at Birmingham, for the purpose of maturing the details of these processes before inviting manufacturers to adopt them. The first furnace erected at these works is one for melting the higher qualities of steel in closed pots, and contains sixteen pots of the usual capacity. The second, erected in 1867, is an open-hearth furnace, capable of melting a charge of 24 cwt. of steel every six hours. Although these works have been carried on under every disadvantage, inasmuch as I had to educate a set of men capable of managing steel furnaces, the result has been most beneficial in affording me an opportunity of working out the details of processes for producing cast steel from scrap iron of ordinary quality, and also directly from the ore, and in proving these results to others."

I have already given you a description of the furnace as used for steelmaking; but this is not sufficient for a full under-

standing of the *modus operandi* of the process. Let us suppose that we are commencing operations with a new furnace. This having been dried by means of a wood fire kept alight on the bottom or hearth, the gas valve closing the connection with the tubes of the gas producer, previously described, is opened to a slight extent, as also is the valve for closing the tube by which air is admitted; the reversing valves are fixed to direct the air and gas to one pair of regenerator chambers under the furnace; these are gradually passed through, and the air and gas are conducted through several flues until they meet at a given point in the furnace, when combustion take place, and the flame, passing slowly through, escapes by corresponding flues at the opposite end, and through the other pair of chambers to the chimney flue. I have already stated how the heat, which would otherwise become waste, is caught and stored up in the regenerator, and how—upon the direction of the currents of gas and air being reversed—this heat is taken up by them, and elevates their temperature to a very high degree, so that upon combustion taking place in the furnace, a heat of great intensity is obtained, and that at the exact point where it is most required and is of most advantage. Under this treatment the furnace is gradually made hotter, and the furnaceman commences to make the bottom. This is done by spreading thin layers of a selected sand over the brickwork of the bottom; each layer is fused before another is laid on, so that at last the surface assumes the form of a shallow basin, solid and impervious, and requiring only very slight repair after the working of each charge. The furnace being thus prepared, the pig iron, and heavier portions of the scrap, are charged into the furnace through the doors provided for the purpose; the furnaceman is careful to distribute his charge so as to obtain the greatest effect from the flame that it may be quickly melted, placing the scrap on the banks of the furnace where it may be thoroughly heated prior to being turned down to be dissolved in the bath of melted pig iron. After a time the whole of the pig is melted, the scrap is turned down, and smaller scrap is thrown in at intervals. During these operations the bath has become covered with a coating of slag, which tends to protect it from the action of the flame. This slag the furnaceman endeavors to "clean" as he terms it, that is, to free it from iron, by the addition of limestone or other fluxes. By and by the furnaceman inserts a long-handled spoon, and takes out a sample of the metal, which he cools in water, and aftewards hammers and breaks. By the behavior of this sample—its hardness or malleability, and by the appearance of the fracture—he judges of the stage at which the charge has arrived. After frequent samples taken he is satisfied as to the point of decarburization reached—then samples are submitted to the chemist, who finally passes the charge as being what is required. Thereupon a quantity of spiegeleisen or of ferro-manganese is, after being heated to redness, charged into the bath, and the whole is tapped out into the ladle. This is done by the insertion of a strong-pointed bar into the tap hole, which has been very carefully formed in the process of making the bottom, and closed with a special mixture before throwing in the charge. The ladle is suspended on a carriage, and various means are adopted for bringing it over each of the ingot moulds in turn, when, as in the Bessemer process, the steel is tapped out of the bottom of the ladle. The charges worked in the earliest furnaces weighed, as we have seen, about 25 cwt. each; now 10, 12 and even 16 tons are dealt with in one operation.

This is the Siemens-Martin process; but the Siemens process differs from it in some particulars. Very little scrap, sometimes none at all, is used; but the charge consists mainly or entirely of pig iron, which is placed on the bottom and round the sides of the furnace in the manner previously described. Melting requires four or five hours; then ore, of pure character, is charged cold into the bath, at first in quantities of four to five cwt. at a time. Immediately this is done a violent ebullition takes place; and when this has abated, a new supply of ore is thrown in—the object being to keep up uniform ebullition as nearly as may be. Of course, care is taken that the temperature of the furnace is maintained so as to keep the bath of metal and slag sufficiently fluid; but after the lapse of some time, when the ore is thoroughly heated, and

reduction is taking place rapidly, the gas may be in part shut off the furnace, the combustion of the carbon in the bath itself keeping up the temperature. In the course of the operation, the quantity of ore charged is gradually reduced, and samples are taken from time to time of both slag and metal; when these are satisfactory, spiegeleisen or ferro-manganese are added, and the charge cast as in the previous case. This mode of working takes rather more time than the scrap process, and the consumption of fuel is rather larger; but it has this advantage, that there is greater certainty as to the result, because of the known composition of the materials charged, which can not be the case in dealing with large quantitities of scrap obtained, it may be, from a thousand sources. Then, again, the loss on the pig by the removal of its silicon and carbon is about compensated by the iron obtained from the ore, which has been used to furnish the oxygen for decarbonization.

There is another form of open-hearth furnace, known as the Pernot, which has been adopted at one or two works in France. The hearth is of circular form, is separated from the body of the furnace, and is supported on a movable carriage. It is also so arranged that it can be rotated on its axis, which is inclined at an angle of 5° or 6° to the vertical. In charging the furnace the pig iron, previously heated to redness in an auxiliary furnace, is placed on the bottom, with the whole of the scrap over it. The bed, or hearth, is then made to revolve slowly, and each piece of scrap is alternately exposed to the full heat of the flame, and dipped in the bath of metal which soon begins to form. The fusion is thus very rapid—the whole charge of about five tons—is fluid in about two hours. Samples are then taken out at intervals, and when the metal is sufficiently soft spiegel is added, and the charge is tapped out. It will be seen that in this system also the regenerative system is adopted, the form and positions of the chambers and the ports, or flues, being modified to suit the other portions of the arrangement. When repairs are necessary, either to the bed, or roof, or ports, the carriage is withdrawn so that these may be done with greater ease and with less loss of time. Two of these furnaces have been erected at Blochairn Works, and have been under trial for some time; but at present I am not able to state that there is any balance of advantages in their favor when compared with the modern Siemens furnaces working alongside them.

If you think for a moment on what I have said, you will no doubt perceive that up to this point my sole aim has been to make you acquainted with the different processes by which steel is manufactured, and with the machinery and apparatus used in each; also, that I have hitherto almost disregarded both the raw materials used, and the quality of the resulting product. I set out with the statement that steel is an ally of iron and carbon, and up to the present have directed your attention simply to the means of obtaining this alloy with the desired proportions. As you are aware, good wrought iron has the properties of malleability and ductility to a large extent, and its tensile strength is considerable. Now the addition, within certain limits, of carbon to iron, has the effect of reducing its malleability and ductility; but its tensile strength is increased, and it acquires the property of hardening and tempering when, after being heated, it is suddenly quenched in cold water. I have said that this is the case when carbon is added within certain limits, and it will probably astonish you to know how narrow these limits are; thus, steel attains its greatest tensile strength when only about one per cent. of carbon is present, when it has an elastic limit of about 30 tons, with an ultimate tensile strength of about 60 tons on the square inch of sectional area; but this steel has but little ductility, and is comparatively brittle, hence it is not adapted to the wants of the engineer for constructive purposes, although it may be well suited to other requirements. From this you will perceive that it is necessary for the steelmaker to vary his practice, at one time supplying steel with not more than 1-1000 lbs. per cent. of carbon, having a low tensile strength, but great ductility, as in the sample before you. Next, he is called upon to supply steel for boilers and ships, which shall come within strictly specified limits as to strength and ductility, and the carbon will be 0.15 to 0.20 per cent. Then he may

have to give a steel for structural purposes, with a higher breaking strain, but necessarily less ductility, and the carbon may be increased to, say, 0.3 to 0.35; or, again, a harder steel may be required, especially prepared to resist wearing action without sacrificing strength, &c., as in rails and tires, and the carbon becomes 0.4 to 0.5 per cent.; but still the catalogue is not exhausted, and the maker is called upon to furnish steel with all shades of temper due to carbon between this point and up to 1.25 per cent.

Now, this would be comparatively easy of accomplishment if it always followed that, given the iron and carbon, the tests proposed would be satisfied; but, unfortunately, there may be phosphorus present, when the brittleness of the steel is increased largely, and its ability to withstand a blow greatly impaired. The steel is, consequently, unfit for its purpose, although it has the qualities of working well through the different operations by which it is changed from an ingot to the finished product. Then, again, there may be sulphur present, and what is called "redshortness" results, that is, the steel cannot be forged or rolled at all if it is present in considerable quanties, and only with great care and with imperfect results if only in moderate proportions. If the operations are completed, however, it does not appear that sulphur has any deleterious effect, but possibly may slightly increase the strength of the steel, as it does when present in cast iron. Again, silicon is sometimes found in the steel, and may have been in excess in the iron used, and the resulting quality will be very unsatisfactory, or sometimes copper, and again, redshortness, will trouble the workmen. All these elements have been greatly objectionable to the manufacturer of steel, hence only the purest materials have been used, and the science of the chemist has been very largely called in to enable the manufacturer to choose rightly, and use judiciously, all the materials he requires. Now, Mr. Bessemer has told us that he was unsuccessful in his earlier efforts to produce good steel, because he endeavored to do this from ordinary pig iron; that he was successful when he used Swedish or other iron, free from impurity, and from this circumstance has sprung the great development of the manufacture of hematite pig iron, the purest made in this country, and the best qualities of which are known as No. 1, 2 and 3 Bessemer. These qualities are almost free from sulphur and phosphorus, but contain sometimes as much as five per cent. of silicon, which has been considered by makers of Bessemer steel rather an advantage than otherwise; because, in its combustion, the heat developed is very great, and useful in the working of the charge. For this reason, as well as because of its purity, grey pig iron—the greyness being in part due to silicon—is always used in the Bessemer converter, while in the Siemens process, a closer iron, say No. 3 and 4, is used; but it is always a stipulation that the silicon shall be as low as possible, and that the sulphur should not exceed 0.06, or phosphorus more than 0.05.

Regarding the latter element, however, the belief has always been held, since the make of steel attained such huge dimensions, that methods would be discovered by which it would be eliminated from the iron, and thus the immense deposits of phosphoric iron ores in this and other countries would be rendered available for steelmaking. The immense importance to those engaged in ironmaking of such a discovery naturally stimulated chemists and metallurgists to unwearied research and experiment, but it has been reserved to two young men, Messrs. Thomas and Gilchrist, to practically solve the problem. I cannot stop to fully describe their process, but would simply state that it depends for its success on the possibility of substituting a basic for an acid slag in either the Bessemer converter or the Siemens or other open-hearth furnace. Chemists would not experience any difficulty in producing this slag, with which the phosphorus in the molton iron would combine, and leave the iron practically pure; unfortunately, however, both the converter and the furnace were in all cases lined with acid materials, so that in vessels thus lined it was impossible to retain the basic character of the slag, on which everything depended. What Messrs. Thomas and Gilchrist have accomplished is, in addition to the production of a basic slag by certain specified means,

they have made bricks of basic materials, and of such character that the converters and furnaces may be lined with them, so that the character of the slag shall not be injuriously modified during the remainder of the operation. This discovery, although apparently of so very simple a character, is no doubt destined to produce a revolution in the steel manufacture of the world. I am not sure that, in this country, except in very special cases, it will enable those who use it to compete successfully with those using hematite iron, so long as the latter can be produced at a cost so nearly approaching that of phosphoretic pig iron; but I have no doubt that on the Continent, where phosphoretic pig can be produced in very large quantities and at a very low cost, and where hematite iron was either imported from this country or produced at a high comparative cost, the margin between the costs of the two different kinds of pig iron will enable those who adopt the new process not only to work at a considerable profit over their former practice, but also, by reducing the cost of the steel made, constitute them formidable rivals in their own and foreign markets, and make them independent of supplies of hematite pig iron from this country.

I must now refer to another element which plays an important part in the operation of the steelmaker, that is, the metal manganese. I have referred to "redshortness" as being due to the presence of sulphur in the steel, but Mr. Bessemer, like all other steelmakers since, was troubled with a redshortness in his ingots, due to another cause than the presence of sulphur—this was the presence of either oxygen or carbonic oxide in very appreciable quantities, locked up in small cells, giving the ingot the fault now known as being honeycombed. This defect threatened to be fatal to the process were not a remedy found. Now, some years before this, Heath had discovered the beneficial effect of manganese in the crucible process, and had taught the Sheffield steelmakers to use it either as oxide of manganese or in some carburetted form. They recompensed him by breaking his heart, through the constant litigation to obtain the reward due to his invention. More recently Mushet had patented the use of spiegeleisen, which contained varying quantities of manganese, and he suggested that by using this iron at the close of the blow, the manganese, being readily oxidizable, would combine with the oxygen forming the cells, or honeycomb, and so the difficulty would be got over. This was in fact the case, and from that time to this the alloys of iron and manganese have been constantly growing in importance. You will now understand why I said that the making of steel with a certain quantity of carbon could be easily accomplished—for it was only necessary to "blow" the metal to a certain point in the Bessemer process, or to dilute it, or to burn it out by charges of ore in the Siemens-Martin or Siemens process, until the iron was thoroughly decarburized, then to add a calculated quantity of spiegeleisen (which, with varying quantities of manganese, always contained a nearly uniform quantity of carbon), and the result was attained, if the operation was carefully conducted. But speigeleisen in those days contained only about 9 or 10 per cent. of manganese; and as it was found to be necessary that the steel should contain not less than 0.3 per cent. of manganese, this could not be added without so increasing the carbon that it was impossible to make what we now call soft steel, hence attention was at once given to the manufacture of spiegel as rich in manganese as possible. This was accomplished so far, that as much as 30 per cent. of manganese was obtained. But the manufacture has been carried to a higher pitch in the production of ferro-manganese, where the manganese present has been increased to even 80 per cent. Thus the means of increasing the manganese in his steel without adding to the carbon, or of decreasing the carbon without losing his manganese, was placed in the hands of the manufacturer; and it was rendered possible to produce the remarkably fine qualities of soft steel which have been made in recent years, of which specimens are before you. Thus, manganese is of very great use to the steelmaker, and when used in combination with silicon and iron in the form of the alloy now before you, it enables us to produce the very fine castings which are to be found in this exhibition. This alloy is the invention of the Terre Noire Company in

France, who have made great use of it in the production of fine castings of large size in the shape of marine engine shafts, &c. Their process in the hands of the Steel Company, who are applying it to the production of the various parts of engines, stationary, locomotive, and marine, and to many other important requirements of engineers and others.

Manufacturers were not slow to avail themselves of the opportunity thus afforded them, and the result has been the immense development in the production of "mild steel" or "ingot iron," to which I referred in my opening remarks. Naturally the fitness of this class of steel for ships and for boilers was at once recognized. Having greater tenacity than the best Yorkshire iron, with as large an amount of ductility, also having this higher tenacity nearly equally in all directions of the plate, steel at once commended itself to the boiler maker. The use of steam at higher pressures for marine engines was made increasingly possible. Engineers had already reached the limit it seemed possible to attain while using iron, for plates were now $1\frac{1}{4}$ inch thick in iron. As it was possible to have a boiler of the same strength as iron, with the scantlings of steel reduced 25 per cent., it is evident that by retaining the same scantlings in steel the pressure might be very largely increased with out any increase of risk to safety, or of difficulty in construction. Then, again, it was recognized that if advantage was taken of the superior strength of steel to reduce the thickness of the internal plates of boilers, the increased steam-generating power would be very valuable and useful. Further, in practice it has been found that although steel is much higher in price than common iron, it is much lower than Low Moor or best Yorkshire iron, and that when all the facts of the case are fully considered a boiler may be built of steel at about as low a first cost as one built in the ordinary style of iron. Then, again, the boiler maker has found that he has less trouble with the defective plates when using steel, and this is an important matter to him. It is, then, no wonder that the use of steel for this purpose has very largely developed; and I have the authority of Mr. Parker, of Lloyds' *Registry*, for stating that, with the exceptional case of the "Livadia's" boilers, out of all the thousands of tons of steel boilers which have come under their survey, they have not had one single case of failure or of trouble. There have been cases when, in the course of construction, plates have been torn or cracked, but he states that in every case the cause is known, and cannot be charged against the qualities of the steel used.

The British Admiralty led the way in the "new departure" in shipbuilding so far as this country was concerned; and, in connection with the supply of the material for the construction of the "Iris" and "Mercury" for the Admiralty, I had the honor of reading a paper before the Institute of Naval Architects in London, in which the qualities of the metal were described, and its behavior under various tests indicated. Mercantile owners, however, were very slow to patronize the "new metal," and I well remember the anxiety I then experienced to obtain a contract for the supply of steel for a merchant vessel. This was at last accomplished in Newcastle. The ice was thus broken, but progress was disappointingly slow. The Admiralty followed up their first venture by contracting for six corvettes to be built of steel by Messrs. Elder & Co. The owner of the merchant vessel to which I have referred had such satisfactory returns from her, that he contracted for a second vessel. Meanwhile, the use of steel had been engrossing more and more of the consideration of shipowners and builders, and many small ventures were made, until at length the great companies took the matter up. Messrs Allan led the way with the "Buenos Ayrean," and were quickly followed by the Pacific Steam Navigation Company, Mr. Donald Currie, the Peninsular and Oriental Company, the British Indian Company, the White Star Company, the Cunard Company, the Orient Company, and many others, the latest and grandest of the vessels built of steel being the "Parisian" and the "Servia," launched the other day into the Clyde. I have already named the small quantity of steel which sufficed for the requirements in 1878. It has been stated that in the following year 19,000 tons of steel vessels were launched on the Clyde alone, while last year the tonnage was increased to

43,000 tons. We claim that vessels built of this mild steel are much safer than those built of iron; that there is less risk of loss with them; and we therefore contend that they ought to class higher, and ought to be insured at lower premiums; also that, being lighter, because of the reduction of scantling allowed as compared with iron, their earning power—especially when carrying deadweight cargo—is so much increased that they make very handsome returns for the additional first cost due to the use of steel.

In support of my statement that steel vessels are safer, I might quote many cases where they have withstood trials that would probably have seriously injured iron ships in similar circumstances, but I content myself with referring to two striking instances. The photograph before you shows the steel plates cut out of the "G. M. B.," a vessel belonging to Messrs. James Watson & Co., of this city, after she had been in collision at sea. You will see that they are bent and crumpled up in fearful style, yet not one is cracked. It was the opinion of experts who saw her after the collision that had she been built of iron she must have inevitably sunk. The other is a more striking instance, and was related by Mr. Wm. Denny, of Dumbarton, to the Institute of Naval Architects: "The 'Rotomahana' had a very narrow escape from total loss on 1st of January. She was engaged in an excursion from Auckland to Great Barrier Island, a distance of fifty miles, and was leaving the harbor of Fitzroy (in Great Barrier Island) by a somewhat difficult passage, when she struck on a sunken rock with considerable force. She made some water on the way back to Auckland, as it afterwards turned out, through some rivet holes; these were plugged, and she was enabled to return to Dunedin to be docked. The enclosed report from our marine superintendent will explain the nature of the damage. The worst damaged plate was taken out, re-rolled and replaced. Several frames were set back, and a good job made of the repairs within seventy-two hours. This experience has shown clearly the immense superiority of steel over iron. There is little doubt that, had the "Rotomahana" been of iron, such a rent would have been made in her that she would have filled in a few minutes. A number of frames were set back by the force of the blow; the bulkhead was bulged, and the plate was corrugated, and yet there did not appear one crack anywhere."

Mr. A. Cameron, marine superintendent, thus reported on the case: "On examining the bottom it was found that, on the starboard bilge, at the bulkhead, between the forehold and the stokehole, about 20 feet of the fourth strake from the keel, was all more or less indented; one plate particularly, 14 feet by 3 feet 7 inches by $\frac{1}{2}$ inch thick, being very badly indented between the frames. This plate we decided to remove, and started doing so at 7 P. M. on the 7th instant. The removal occupied twenty-four hours, as all our tools broke in the work, and a new set had to be specially made to stand the steel. The plate looked so bad that it was doubtful whether it was worth while spending any time over it, however we decided to give it a fair trial, and it was put in the furnace, and heated for two hours, then taken out and hammered on the blocks. This process had to be repeated three times before the rollers would take it in, but when it had passed through the rolls, it really looked like a new plate, perfectly sound and good. In working it stretched $\frac{3}{16}$ths of an inch, but by paring a little of the ends, the rivet holes, at both the landings, and the butts came in exactly as required for a true fit. Seven of the frames were badly bent, with a sharp curve tending both inwards and aft, two being bulkhead frames, with double angles, and very strong. The floors were cut, and the frames thoroughly examined, but we found no sign of crack or strain in the material. The frames were heated and re-straightened, and riveted to the floors. All the riveting was completed by 6 P. M. on the 10th instant. It may be here stated that, had the frames been composed of iron, instead of the splendid ductile material of which they are composed, they would all require to have been renewed; and, even then, they would not have made such a complete job as the present.

But what are the alleged disadvantages of the use of steel? First, that its cost, as compared with iron, is too great. This objection was a formidable one

when plates were sold at nearly £20 a ton, but since then constant and unremitting efforts have enabled steelmakers to reduce the price within such limits as may be called reasonable, and will enable the vessel to earn a good return on the increased expenditure. Doubtless the increased competition due to the rapid extension of steel works will sharpen our wits, and compel us to adopt, or to find out, means of producing at a lower cost, that so the demand may be sufficiently increased to find occupation for us all. I am informed that there will be built this year, under Lloyd's survey alone, something like 700,000 tons of shipping, requiring in its construction from 250,000 to 300,000 tons of iron or steel, and although this may be an exceptional year, yet it will not be for want of great exertions on the part of steelmakers if they do not obtain a due share of orders, which are sufficiently large to employ at least six times the power of production possessed by the Steel Company of Scotland. Then it is stated by some inexperienced people that steel is more difficult to work in the shipyard. Against that I may quote the testimony of those who have used steel most extensively. Messrs. Denny, who have had contracts requiring 18,000 tons of steel, inform me that their men prefer working steel rather than iron, and that if they could obtain contracts for steel vessels, sufficient to keep their yard full, they would not build another iron vessel. Further, it is stated that steel vessels, being built with reduced scantlings, want stiffness. Now, this being the result of unsuitable designs, the metal not being properly distributed, it is evident that the skill of our naval architects will quickly remedy that defect, if it exists in reality, and not in the imagination of the hypercritical only. Then a great deal is said about corrosion. But this cry of the liability of steel to excessive corrosion, if not raised, has been greatly magnified by our friends, who, by the animus evident in what they say and write, appear to indicate that they are not particularly disinterested in their statements. A great deal has been made of the case of the "Iris," which the Admiralty have had examined; but I have it on undoubted authority that the case has been greatly exaggerated, and that the officials at the Admiralty had experienced no uneasiness or alarm in regard to her condition. As positive evidence against the statements as to corrosion, I can refer to many instances in which the anxiety of owners have led to careful examinations of ships and boilers built of steel, without discovering any trace of corrosion or pitting. I feel, therefore, that I am warranted in speaking strongly against the efforts being made to damage the character of steel in this respect.

Now I come to consider what appears to be the most serious charge of all. It is fashionable amongst a certain class to talk of the "mysterious behavior of steel"—to shake the head, shrug the shoulder, look wise and serious, and talk of its "unreliable character," "its utterly untrustworthy qualities," in strains which make the inexperienced feel that the less they have to do with steel the better. Now for a long time we have accepted all this condemnation as meekly as might be; we have occasionally ventured to express our opinion that unwarrantably hard things were being said of steel, that we hoped all was not true that was said, or at least that the statements were somewhat exaggerated.

We have endeavored by careful work to prevent accumulation of evidence on the part of accusers, have "bided our time" until the use of steel should be greatly extended and until the people using it should be greatly increased in number. I think the time has now come when we can assume a different attitude, and, allowing our enthusiastic feeling with regard to steel to have full sway, say to the detractors "Upon you lies the onus of proof" that steel is unreliable in character and untrustworthy in use as compared with iron. We direct you, in refutation of the statement, to the rigid character of the tests we undergo while anything that will hold together in the shape of iron may be put into a ship. We ask you to note the extremely few failures which have occurred in steel, in the shipyard, and contrast it with the failures in iron. I remember that when nearly 7000 tons of steel had been used in one of our shipyards not more than three plates had failed in working, and it was admitted that in two of these no fault could be found with the metal;

while in the same yard a small vessel was being built requiring about 40 tons of iron, and I saw not less than seven plates which had failed in working. During the time that Lloyds insisted upon rigidly testing steel in the ship-yards instead of at makers' works, the total rejection of plates, &c., for not satisfying the required rigorous tests was very small indeed, and those which were so rejected were very much superior in quality to the iron in common use. Why, then, should we steelmakers submit to this stigma being attached to our production? We know that although there may be some few exceptional failures, yet they form an infinitesimal porion of the very large whole of our make; the metal which we send out of our works is worthy of the utmost confidence, and justifies the pride with which we refer to its many good qualities.

I have long felt very strongly on this point, and although it has not, I am happy to say, fallen to the lot of my company to have many complaints as to the quality of their productions, but rather the reverse, I have felt that scant justice has been done to makers of "mild steel," who have spared no expense or care in their efforts to achieve the success at which they have arrived, and who have sought for and made use of all the knowledge, scientific and practical, which was within their reach.

ENERGY EXPENDED IN THE MAGNETIZATION OF IRON.

By A. NIAUDET.

Translated from "l'Electricien."

The heating of an iron bar that is rapidly and repeatedly magnetized and demagnetized is a familiar fact.

It was specially noted by Siemens when he first employed his rotating armature between the poles of a permanent magnet.

If the alternating current from an Alliance machine be passed through a helix, within which is placed a small piece of iron, the latter heats rapidly. In view of this fact, we are led to inquire whether the heat is produced at the moment that the magnetism is excited, while it continues, or at the instant it ceases.

A permanent magnet may be compared to a coiled spring. A certain amount of force is necessary to coil the spring; it is equally necessary in charging the magnet. It is manifest that a magnet possesses a certain amount of energy; it is capable of raising its armature, and with it a certain amount of weight; but while sustaining the weight it is incapable of exerting this force anew. It is like the spring uncoiled. If the armature be detached the work previously performed by the magnet must be performed in the inverse direction, and the capacity of the magnet to attract is restored. It resembles the spring rewound. During the intermediate period the armature is held at rest; there is no expenditure of work.

Now, considering the case of an electro magnet, it appears *a priori* evident that the expenditure of a certain amount of energy is necessary to produce the magnetism. But when once produced is any expenditure necessary to maintain it? And, finally, when the magnetism ceases what becomes of the energy?

Experiment affords replies to these questions

Establish two derived circuits, having equal resistances, so that the partial currents shall be equal, and so that their equality shall be established by a differential galvanometer. If one of these circuits contains a helix, and a bar of iron be inserted, the equilibrium between the derived currents is immediately disturbed. An increased resistance is exhibited in the current which has been made to encircle the iron rod. But the disturbance is only temporary; the galvanometer again returns to zero, and proves the restoration of equilibrium. This experiment indicates an expenditure of energy in the *production* of the magnet, but it proves also that no expenditure is necessary to *maintain* the magnetism after it is once produced.

There is evidently no difference be-

tween the two currents, one of which maintains the magnetism of a bar of iron, while the other does not. The expenditure of energy in the cases is the same, and it costs nothing to maintain the magnetism. In both cases the effect is entirely calorific.

But it must be observed that if the current ceases the magnetism disappears; consequently the maintenance of the electro-magnetism demands an expenditure of energy which can be calculated when the resistance R of the coil about the bar, and the intensity I of the current, are both known. It is equal to RI^2.

The above explanation may be illustrated by a mechanical example: A kite requires no expenditure of work so long as it remains at the same height; but if the wind suddenly ceases the kite falls, and so proves that it only maintains its place in the air by a certain amount of work of the wind.

M. Ayrton communicated to the Société de Physique, in January last, the result of some experiments upon the above phenomena. He made use of a highly intense magnetizing current; he took the precaution to pass a current of water, of constant temperature, through the annular space between the wire coil and the iron core; he employed for the temperature a thermopile of great sensibility. He never detected the least heating of the iron as a consequence of maintaining the magnetism of the iron.

The third phase of the phenomena, the cessation of the magnetism, remains to be examined. We have seen that the magnet absorbs energy at the moment that it is magnetized. What becomes of this energy when it is demagnetized? It seems indisputable that it must appear in the form of heat, and we find in this fact the explanation of the phenomenon mentioned in the beginning of this article—the heating of a bar when it was magnetized and demagnetized rapidly a great number of times.

Now applying these principles to the study of dynamo-electric machines, we see that during the short period required for the magnetic charge, there is an expenditure of energy corresponding to the production of the magnetism.

During the regular working of the machine there is no expenditure of work for the maintenance of magnetism, so to speak; but there is actually an outlay of calorific energy in urging the current through the coil of wire; an expenditure measured by the formula $\frac{RI^2}{9.81}$ kilogrammeters. The period of demagnetization is without interest.

The above remark supposes the current constant. If it is periodically variable, there will be an expenditure of work each time that the magnetic charge is raised from its least value to its greatest.

The current of the Gramme and the Hefner Von Altneck machines is undulatory, and would be absolutely constant only when the number of the sections of the coil became infinite. But practically when the Gramme ring is composed of sixty sections, the current may be considered as constant, and the variations caused in the magnetism of the electro magnets may be neglected.

ELECTRIC RAILWAYS AND TRANSMISSION OF POWER BY ELECTRICITY.

By ALEXANDER SIEMENS.

From the "Journal of the Society of Arts."

When electricity was first utilized for practical purposes, the cost of producing it precluded its application to anything but giving signals or working small and delicate apparatus, requiring only weak currents to perform their functions; but by the discovery of the dynamo-electric principle, some fourteen years ago, powerful electric currents have been placed at our disposal, at a cost which enables us to transform into commercial processes a number of experiments which, up to that time, served only as illustrations of scientific lectures.

The machines which have caused this

revolution in the application of electricity consist essentially of two parts—the fixed electro-magnets, by which a powerful magnetic field is created, and the revolving armature, which is connected with the commutator. When the machine is in action, the rapid motion of the copper wire through the magnetic field induces an electric current, which leaves the helix by the brushes pressing against the commutator on opposite sides. From the brushes the current passes to the electro magnets, and afterwards to the outer circuit, where it has to perform the useful work. In traversing the coils of the electro magnets, it increases the intensity of the magnetic field, which in its turn induces a more powerful current, and this mutual strengthening of current and magnetic field goes on until a balance establishes itself in the manner afterwards described.

The researches of Sir William Thomson, Dr. Hopkinson, Professor Ayrton, and others have proved that such machines, if properly constructed, will render in the form of electrical work up to 90 per cent. of the energy expended upon them in the form of motive power. It may, therefore, be conceded that they are very efficient transformers, and that we can hardly hope to exceed the results already obtained by the best types of dynamo-electric machines. If, instead of using such a machine to generate electricity, you send a current into it, the magnetic attraction created between the poles of the electro magnets and the currents traversing the armature will cause the latter to rotate, and this motion can be communicated to other machinery in the usual ways. A pair of such machines, one for producing electricity and the second for re-transforming the current into motive power, can, therefore, be utilized for transmitting power to a distance. In order fully to understand the manner in which this transmission is effected, a large number of experiments were made at the works of Messrs. Siemens and Halske, in Berlin, by Dr. Frölich, and the results obtained were laid before the Royal Academy of Science, in Berlin, by Dr. Werner Siemens, on the 18th November, 1880.

The principal conclusions arrived at were the following: On applying Ohm's law to a magneto-electric machine (a machine with permanent magnets) we find that the strength of current for a given total resistance is:

$$(1) \qquad C=\frac{n\times M\times v}{R}$$

In this formula C signifies the strength of current; n, the number of convolutions of wire on the armature; v, the number of revolutions per minute; R, the total resistance in circuit; M, the total E. M. F. produced by the permanent magnets and the iron of the armature in one convolution of wire, when $v=1$; this quantity will afterwards be called "effective magnetism" of the machine.

The same formula holds good for a dynamo-electric machine. In this case, however, the "effective magnetism" (M) depends on the strength of current (C), and the formula, by substituting f (C) for n (M), becomes:

$$(2) \qquad C=\frac{vf(C)}{R}; \text{ or } \frac{C}{f(C)}=\frac{v}{R}.$$

In the latter form, the very important law is expressed that the strength of the current in a given dynamo-electric machine depends only on the ratio of the number of revolutions per minute to the total resistance in circuit. If we determine, therefore, f(C) for a machine, we can calculate beforehand the strength of current it will produce with a given number of revolutions in a given resistance.

The first series of experiments was made to test the correctness of this conclusion, and the curves I., II., and III., embody the results obtained by working one of the largest "Siemens'" dynamo machine (type D_0.) through various resistances at different speeds. The total resistance of the machine was, in case (I.), .435 S. U.; in case (II.), .725 S. U.; and, in case (III.), .714 U. S.

By way of comparison, the curve IV. was set out from results published by Messrs. Meyer and Auerbach in "Wiedemann's Annalen," Band 8, p. 494, who had experimented with a "Gramme" dynamo machine. As will be seen, all these curves do not differ materially from a straight line, and, for the limits of practical working, they fully confirm the above theory. There exists, therefore, a curious similarity between magneto-elec-

tric and dynamo-electric machines. In both, the strength of current is proportionate to the ratio of revolutions per minute to total resistance, although the magnetism of the magneto machines is a constant quantity, and that of the dynamo machines varies with the strength of current. The important difference between the two kinds of machine is, that magneto machines give a current however slow their motion is, whereas dynamo machines only begin to give a current when the ratio of number of revolutions to total resistance attains a certain magnitude.

The nature of the $f(C)$ was then further examined, and the influence on the magnitude of the "effective magnetism" of the currents set up in the iron of the armature by its quick rotation in a magnetic field, and by the currents traversing the coils of the armature. The results arrived at are represented by the curves V., VI., VII., for the large Siemens machine, and by the curve VIII. for the Gramme machine referred to above. They show that at first the "effective magnetism" increases in proportion to the increase of current, then it deviates more and more until it very gradually reaches a maximum, and for still more powerful currents it decreases again. The latter peculiarity is to be accounted for by the fact, that the iron bars of the electro magnet cannot be magnetized beyond a certain point, whereas the diminishing influence of the currents on the magnetism in the iron of the armature increases continually with the strength of these currents. In practical applications such powerful currents are seldom met with, and it will suffice for the present purpose to assume, that the "effective magnetism" gradually approaches a maximum.

When two machines, identical in their construction, are connected to transmit power, the "effective magnetism" in both should be equal, as the same current circulates through both of them. The following equations will, therefore, exist between the various quantities:

$$E_1 = nMv_1 ; \quad E_2 = nMv_2 ;$$

$$C = \frac{E_1 - E_2}{R} = nM \times \frac{v_1 - v_2}{R} ;$$

$$W_1 = a \times E_1 \times C = aC^2 R \frac{v_1}{v_1 - v_2} ;$$

$$W_2 = a \times E_2 \times C = aC^2 R \frac{v_2}{v_1 - v_2} ;$$

$$H = a \times C^2 \times R ; \quad W_1 = H + W_2 ;$$

$$N = \frac{W_2}{W_1} = \frac{v_2}{v_1} = \frac{E_2}{E_1}$$

In these formulæ the index 1 refers to the machine producing the current, and the index 2 to the machine giving out the power; E stands for electro-motive force; n, M, v, P, C, signify the same quantities as before; a is a constant depending upon the construction of the machine; H is the heat, generated in the system; W_1 is the work expended upon the primary machine; W_2 is the work given out by the secondary machine; N is the useful effect.

In comparing these formulæ with observations, it is easily seen that they can not be quite correct. This is most conspicuous with the formula for the useful effect, $N = \frac{v_2}{v_1}$, according to which this should be greatest the more the velocity of the second machine approaches the velocity of the first machine, whereas actual experiments show that N is a maximum for a certain velocity of the second machine, and will decrease for any greater or lesser number of revolutions of the secondary machine. The cause of this discrepancy is the influence of the so-called Foucault currents, which are set up in the iron of the revolving armatures by the proximity of the powerful electro magnets.

In the primary machine these currents circulate in the same direction as the currents in the covering wire of the armature, and by weakening the "effective magnetism," and, consequently, the E_1 M.F $- E_1$, they increase the work W_1 expended upon the primary machine. In the secondary machine, however, in which the armature turns in the opposite direction, these Foucault currents circulate in the opposite direction to the currents of the armature wires, and by thus strengthening the effective magnetism and the electro-motive force E_2, they diminish the work W_2, given out by the secondary machine.

As our machines are supposed to be of identical construction, the following formula will express the relative propor-

tion of the different quantities relating to the Foucault currents:

$$M_1 = M - ec_1 ;\ M_2 = M + ec_2 ;$$

$$c_1 = \frac{M_1 v_1}{u} = \frac{1}{n} \cdot \frac{E_1}{u_1} ; c_2 = \frac{M_2 v_2}{u} = \frac{1}{n} \cdot \frac{E_2}{u} ;$$

M signifies the effective magnetism, such as it would be, if no Foucault currents existed; M_1 and M_2, the actual effective magnetism of the two machines; c_1 and c_2, the strength of the Foucault currents; u, the resistance through which these currents circulate; v and n, having the same meaning as before; and e being the constant, depending on the construction of the machines.

If we calculate from the above equations the value of M_1 and M_2, substituting at the same time $y = \frac{e}{u}$: we have

$$M_1 = M(1 - yv_1) ; M_2 = M(1 + yv_2) ;$$

and for the electro-motive force of the two machines,

$$E_1 = nM_1 v_1 = nM(1 - yv_1)v_1 ;$$
$$E_2 = nM_2 v_2 = nM(1 + yv_2)v_2 ;$$

this gives us for the current,

$$C = \frac{E_1 - E_2}{R} = \frac{nM}{R} [v_1 - v_2 - y(v_1^2 + v_2^2)] ;$$

and for the work expended and given out respectively,

$$W_1 = anCM_1 v_1 + ac_1 M_1 v_1 ;$$
$$W_2 = anCM_2 v_2 - ac_2 M_2 v_2 ;$$

or if we substitute $p = \frac{a}{n_2 u}$:

$$W_1 = aCE_1 + pE_1^2 ;\ W_2 = aCE_2 - pE_2 ;$$

$$N = \frac{W_2}{W_1} = \frac{E_2}{E_1} \left\{ 1 - \frac{p}{aC} (E_1 + E_2) \right\} ;$$

$$H = aC (E_1 - E_2);\ F_1 = pE_1^2;\ F_2 = pE_2^2;$$
$$W_1 = W_2 + H + F_1 + F_2.$$

In these formulæ the symbols have the same signification as before, and F_1 and F_2 signify the work done by the Foucault currents.

The electrical quantities E_1, E_2, and C admit of an easy measurement, and by the help of the above formulæ, the quantities W_1 and W_2 can be determined beforehand, when the constants of the machines are known.

A great number of experiments were then made, in which all the quantities were measured, and the observed results were compared with the quantities calculated from the above formulæ, and it was found that they agreed very well. It is hardly necessary to observe that these formulæ are applicable to all types of dynamo-electric machines, whatever their construction may be, the character of each type determining the constants.

The idea of utilizing these machines for transmission of power presented itself to Dr. Werner Siemens as long ago as 1867, when he discussed at the Paris Exhibition with other members of the jury the possibility of elevated electric railroads; but the dynamo machine was at that time not sufficiently developed to admit of a practical execution of the idea, and when the present more perfect forms were invented electric lighting monopolized for a time all the attention that was bestowed upon the practical application of the machines.

During the efforts which have been made to introduce electric lighting on a large scale, the idea of applying the light-giving machines during day-time to distribute power, has come to the front again, and as such an application means a further utilization of the invested capital, the combination of lighting with transmission of power is sure to be made.

For this purpose a central station has to be established in a district, in which powerful steam engines, working on the most economical principles, drive a number of dynamo machines, which produce the electric currents. Secondary batteries, similar to those constructed by M. Planté, and improved by M. Faure, may be employed to receive the electricity, and keep it ready for use in the same manner as the gas is stored in large gas holders, and as accumulators are used in connection with hydraulic machinery.

From the station cast-iron pipes are laid through the streets, similar to those now in use for distributing gas or water, and insulated wires are drawn into them for conveying the currents from the machines to their destination. At convenient intervals the wires are made accessible by so-called "road boxes," inserted in the pipes, from which the connection to houses or lamp posts can be made. Two separate sets of wires would be required for the lighting and for the transmission of power, the com-

mutators, for directing the currents, being placed in the station ; and additional commutators could be fixed in the houses for switching the current from secondary machines to lamps, without communicating with the station.

There is no doubt that much has to be learnt before all the details of such a central station, and of a practical system of distribution have been brought to perfection ; but there are, now-a-days, few obstacles that cannot be surmounted, and even our present knowledge is advanced enough to teach us that there is nothing impossible in the idea sketched out above.

When a certain amount of power has to be transmitted by electricity to the given distance, it is easy to determine, experimentally, what power is required to drive the primary machine, as the exact conditions, under which the trial was conducted, can be readily reproduced in the practical application. In this respect, the transmission of power by electricity possesses a great advantage over the transmission of power by water or air, as the friction and leakage of the pipes, through which the latter have to be conducted, can never be determined in advance. It further has the advantages that the secondary machine works without producing any waste, which has to be disposed of, and that the small size and low weight of the machines obviates the necessity of heavy foundations for them.

In considering the possibility of employing the electric current to distribute power from a central station, the proportion of the power given out by the secondary machine to the power expended upon the primary machine, will not be of that deciding influence, as is generally supposed. Granted even that not more than 45 per cent. of the power expended can be reclaimed, it will still be possible to produce the power required at a cheaper rate, than if each small place had its own steam engine. For, at the central station, 1 h.p. could be produced by the large steam engines with about $2\frac{1}{4}$ lbs. of coal, so that 1 h.p. given out by the secondary dynamo machine would be produced by burning 5 lbs. of coal per hour. There are few small steam engines which will produce a horse power with that expenditure of fuel, and if we take into account the trouble and risk connected with the running of steam engines, it may be readily admitted that this loss is no real obstacle to the introduction of the electrical transmission of power. Of still less consequence will this loss be where waterfalls or other natural forces can be employed to drive the primary machines, in which case the power would cost practically nothing, beyond the interest on the capital and the depreciation of the machines. The applications which it has hitherto found have, to a certain extent, been of a tentative nature only, and on a small scale, but they are nevertheless very instructive, as they show that economical results can be obtained by it.

About three years ago, Sir William Armstrong erected a turbine at his country seat, Craigside, near Newcastle, and drives by it a Siemens dynamo-electric machine, the current of which is conducted to his residence about half a mile distant from the waterfall. In day-time this current transmits the power of the turbine to the house, where it is used for various purposes, and at night it is converted into light by means of "Swan" lamps, of which it works between thirty and forty. This application deserves special mention, because it is one of the earliest examples of transmission of power by electricity for practical and permanent purposes.

In the same way Dr. Siemens utilizes some dynamo machines at his country house near Tunbridge-wells, the power to drive the primary machines being, in this case, obtained by means of a Tangye "Soho" steam engine. The waste steam from the engine is utilized to warm the hot houses, and the gardener attending the houses takes also care of the steam engine and the dynamo machines driven by it. In this way the cost of fuel and of attendance is reduced to a minimum.

The electric current is utilized during the whole of the night to produce two lights, by the influence of which various fruits and plants are growing ; and the current, in daytime, from one machine sets in motion a similar machine, which works the chaff cutter, and some other machinery, at the farm about a quarter of a mile away from the hot houses. The current from the other machine is conducted to the pumping house, a distance

of about half a mile, and the secondary machine there has supplanted a small vertical steam engine that used to pump the water up to the house. In this case, the return conductor is formed by the wire fence, care being taken to connect the wires from one side to the other of the intervening gates.

By these arrangements, one man at the farm can do the work of three; and, instead of a man having to drive a steam engine at the pumping station, to say nothing of transporting coals there, and losing time in getting up steam, he can set the pump in motion without going near the place, an occasional visit only being required for refilling the lubricators.

There are many similar instances, in which it is advantageous to connect a number of small machines, which work at irregular intervals, by means of the electrical transmission of power with one steam engine, not only when the distance between the machines is considerable, but also when they are comparatively close together.

Several applications of the latter nature have been made at Messrs. Siemens' works at Charlton; among others the apparatus for testing the mechanical strength of cables, is set in motion by a dynamo machine; and a small pump, which keeps the water in circulation in the core tanks, is driven by another machine. In both cases it would have been more costly to transmit the necessary power in the usual way by shafts and belting. A few months ago a machine was placed upon a crane on the wharf, and it was found that by it a ton could be lifted about 12 feet per minute, and smaller weights proportionally quicker. It is only fair to add, that the crane was not constructed for the purpose, and that the arrangement was made more with the view to demonstrate the possibility of working cranes by electricity, than to obtain the best results.

The electrical transmission of power, on account of the compactness of the machines, and the ease with which the conducting cables can be shifted, is particularly adapted to be used in cases where the driven machinery is erected only for temporary purposes. As an example, it may be mentioned that, when the cable ship "Faraday" was last at the works of Messrs. Siemens, the machinery, by which the cable is pulled on board, was driven part of the time by a dynamo-electric machine.

Another illustration of the same kind was furnished by M. Felix, of Sermaize-les-Bains (Marne), who worked, in June, 1879, one of Howard's double-furrow plows by a Gramme dynamo machine. The motion was conveyed from the electrical machine to a drum, and thence by a coil of wire to the plow. There was no stoppage of any kind, but the plow did its work steadily, digging up the ground to the depth of about eight inches. In the following year, M. Felix showed at the local agricultural exhibition at Bar-le-duc a plow and a threshing machine, both worked by electrical transmission of power, with perfect success.

As mentioned above, one of the first thoughts of Dr. Werner Siemens was to employ dynamo-electric machines for working elevated railroads, but it was only about three years ago that he was induced to take the matter into serious consideration, by the owner of a coal mine asking him to design a locomotive to draw the coal wagons in the mine. The result was that Messrs. Siemens and Halske showed at the Berlin Exhibition, in the summer of 1879, the model of an electric railway, which has since been exhibited at Dusseldorf and Brussels, and is at present working in the Crystal Palace. The total length of this circular railway was at Berlin 300 meters, and the gauge one meter. A dynamo machine, mounted on a carriage by itself, served as locomotive, and the passengers were conveyed in three carriages, each having seats for six persons. The current was conveyed from the primary machine to a rail laid between the rails on which the carriages run; thence it was taken off by brushes fixed to the machine and sliding on the center rail, it returned to the primary machine by the outer rails. When the carriages were prevented from moving, the locomotive exerted a pull of about 4 cwt. (200 kilos.) on them; and when the train was in regular motion, the pull varied between $1\frac{1}{2}$ cwt. and $1\frac{3}{4}$ cwt. (70-80 kgr.) which represents, as the speed was about 10 feet (3 meters) per second, three-horse power.

Small as the railway was, it clearly

demonstrated that such a mode of transport is feasible; and the advantages of having light carriages, of being able to propel them without noise and smoke, induced Messrs. Siemens and Halske to lay before the authorities in Berlin a plan to make an elevated railway through one of the streets in Berlin, altogether about 6¼ miles (10 kilom.) long.

Along the curbstones of the streets, iron columns, formed by two-channel irons, were to be erected, about 11 yards apart, carrying wooden sleepers on top, which, in their turn, support longitudinal girders. To ensure the stability of the structure, wooden struts keep the girders apart, and serve, at the same time, to insulate them from each other. The clear height, from the level, of the street to the under side of the girder is about 14 ft. 6 in. (4.4 meter), and the depth of the girder about 16 in. (40 cm.) Steel rails are laid on top of the girders, and the girder and rail on one side serve as the conductor from the primary machine, and the other rail and girder form the return wire; in this way the electrical resistance of the line is reduced to a very low figure.

The gauge of the line was to be one meter, and the carriages, resembling ordinary tram cars, were to be about 5′.5″ broad (1.65 m.) and 8 feet (2.46 m.) high above the rails. The dynamo machine, placed out of sight, underneath the car, imparts the motion by means of belts to the two wheels, which have to be insulated from each other, as the current arrives through one rail, passes through the machine, and returns by the other rail as described above.

The speed these carriages were intended to travel is 30 kilometers (18.6 English miles) per hour, and ten of them were to be supplied for the railway, of which six would be in use, and four in reserve, 10 h. p. being required to drive the primary machine of each carriage, The cost was carefully worked out, and, as it serves as an indication what such railways may be expected to cost, a short summary of the principal items will not be out of place:

FIRST COST OF 10 KILOMETERS (6¼ MILES), ELEVATED RAILWAY, SINGLE LINE.

Railway itself, including 10 stations.	£61,000
Ten carriages, to hold 15 persons each	3,150
Stationary steam engine and dynamo-machine	1,950
Buildings	1,185
Land	4,500
General expenses	715
	£72,500

or about £11,600 per mile.

This estimate includes the cost of erection of the railway, and of the station, at which the steam engine works, together with the necessary buildings to protect the rolling stock against the weather, when it is not used. The cost of working the railway was calculated to be, for one year:

CURRENT EXPENSES.

Wages	£2,190
Fuel	1,110
Oil and waste	50
Lighting	80
	£3,420

DEPRECIATION AND REPAIRS.

3% on £72,500 (railway and buildings).	£1,875
16% on £5,000 (carriages and machinery)	800
	£2,675

INTEREST ON CAPITAL.

5% on £72,500	£3,625
Total cost per annum	£9,720

or about £4 6*s*. per English mile per day.

The intention was to run about 200 trains per day, and if the charge of 1*d*. per mile had been made, the £4 6*s*. per mile could have been earned, if on the average five or six persons had been conveyed in each case. The concession for this railroad was not granted, partly because the inhabitants strongly objected to having people looking into their first floor windows, and partly because the Emperor did not wish to see "The Linden," which this electric railway was to cross, disfigured.

Subsequently, Messrs. Siemens and Halske obtained permission to build a railway on the ground level from Lichterfelde, a suburban station on the Berlin-Anhalt Railway to the Military Academy, and this railway has just been successfully opened for regular traffic. It is a single line of 1 meter gauge, a little over 1½ English miles long. The permanent way has been constructed in exactly the same way as that of railways; wooden sleepers and steel rails are employed, the rails being connected, in addition to the

usual fish plates, by short straps of iron, bent in the shape of a bridge, so as to admit the adjustment of the rails to different temperatures, and to reduce at the same time the electrical resistance. As the currents are low-tension currents, it was not necessary to provide further insulation, and no difficulty is experienced in using one rail as the positive, and the other as the negative conductor.

About a third of a mile from the Lichterfelde station the primary machine, with its steam engine, is erected in the engine house of the water works, and the current is conveyed from there to the rails by underground cables. The car is exactly similar to an ordinary tram car, and is constructed to hold 20 persons besides the guard. It is symmetrical, and can move backward and forward, each end being provided with a starting lever for the guard, a brake handle and a signal bell. The dynamo machine is placed underneath the car, and transmits its movement to the wheels by means of spiral steel springs. The tires of the wheels are insulated from their axles, and are in electrical connection with brass rings, fastened on the axles, but insulated from them. Contact brushes press against these brass rings, and from them the current is conducted to the dynamo machine, and sets it in motion.

The authorities were, for some time, doubtful how to class this novel railway, and after long deliberation they have decided to rank it as a one-horse tram car. In consequence of this decision, the average speed on the railway must not exceed 9.3 English miles (15 kilometers) per hour, and the greatest speed at any moment must not exceed 12.4 English miles (20 kilometers) per hour. The time for traversing the whole distance is, therefore, not to be less than ten minutes, although the car could make the journey in about half the time with perfect safety.

If the railway continues to work in a satisfactory manner it is to be extended, and there is no doubt that the success of the railway at Lichterfelde will greatly assist in the further introduction of electrical railways, either on the level of the streets, or elevated, like the steam railways of New York. Over any other system, worked by steam or by compressed air, the electrical has the advantage that no heavy machinery has to be carried about to set the train in motion. The carriages can, therefore, be built in a lighter manner, thus reducing the power necessary to move them, and permitting all bridges and other superstructures to be built more cheaply than usual. Several carriages, each with a dynamo machine, can be joined to one train, and by this distribution of the motive power much steeper inclines can be overcome than when the same train is drawn by a single locomotive.

In addition to the ordinary brakes, means can be provided to short circuit the machines on the carriages, and to cause them in this way to act as very powerful brakes. The use of large stationary engines reduces the amount of fuel necessary to develop a certain power on the traveling carriage, and if waterfalls can be utilized, the cost of working these railways will be further diminished. It seems, therefore, probable that such railways can be usefully and economically constructed to facilitate the traffic in crowded streets, or in situations where local circumstances favor their application.

From all that has been done during the last few years, it is quite evident that the art of transmitting power by electricity has advanced rapidly, and that its practical application is continually gaining ground. This, however, should not be regarded as a sign that the electric transmission will supersede every other system of transmitting power to a distance, but rather that there is a sphere for it, where it meets existing demands better than our present means; and it should, therefore, not be treated as an enemy of existing systems, but as a supplement to them, by the aid of which problems can be solved, that could not otherwise be attempted.

DISCUSSION.

The CHAIRMAN said the subject brought before them that evening was one which, though of the highest importance, had been presented in a modest, unassuming manner; but there was in the paper matter for very deep consideration. The great utility of some means of transmitting power to a distance had long been recognized, and must be appreciated by all who thought on the subject. The

same argument was frequently made use of which had been advanced to-night, that if power could be laid on to houses in small quantities, it might turn the course of industry from the system of large factories to a system in which each workman might work in his own dwelling; but he was not at all prepared to say that such a change, except in special cases, was desirable. The probability was that the workman would have bad ventilation, that he would not attend to his duties so well as he would in a large factory, and that all the economies arising from a well-organized establishment and the sub-division of processes would be done away with, the only advantage being the somewhat sentimental one, that the man worked in his own house. However, this was rather a question for the political economist than for an engineer. Attempts at transmitting power from a distance had been made for many years. He was apprenticed to an engineer (John Hague) who was the very earliest to make the attempt on a large scale. His mode was the exhaustion of air by pumps worked by water wheels or other suitable prime movers, the exhausted mains being connected to engines in the nature of a steam engine, and the pressure which the atmosphere exerted on the piston caused it to work. In that way power was conveyed very well indeed—considering the time at which it was done—and very usefully. Notably, it was conveyed to underground engines in coal mines, where it provided a motor free from the objections of steam engines in such positions; it was also conveyed from a steam engine into gunpowder manufactories, so as to obviate the necessity of fires within the manufactory. Since then they had had the transmission of power by compressed air, and also by water under pressure, as perfected by Sir William Armstrong, by means of accumulators and various hydraulic engines. He could not quite agree with Mr. Alexander Siemens, that the great advantage in the electric mode of transmission over these last two, lay in the fact that with them the loss by friction and leakage could not be accurately calculated; because the loss by friction was easily calculated, and that by leakage was dependent on the care with which the work was carried out, and it ought to be, and was in fact, extremely small. Then again, there was the transmission of power by means of endless ropes, of which there was a magnificent example at Shaffhausen, where the water of the Rhine was made to work large turbines which drove endless ropes: these were carried about three-quarters of a mile along the bank of the river, and drove shafting under the side streets, from which the power was laid on to various houses, and he did not know a more interesting sight than to see the power of the Rhine thus utilized. But this evening we had before us a means of transmitting power by electricity, and no doubt if such a slender conductor as was on the table could be substituted for the large exhausted main of John Hague, for the smaller main carrying compressed air, or the still smaller one carrying water under pressure, or for the rope running over guide pulleys; a great step would be gained. Mr. Alexander Siemens had put it that this mode would be economical even supposing only 45 per cent. of the power developed in the steam engine was available at the spot where it was utilized, and did so, on account of the greater economy in working one large central steam engine, rather than a number of small ones, and in that he quite agreed with him, as also in the statement that $2\frac{1}{4}$ lbs. of coal per h. p. was a liberal allowance for a large condensing engine, and that at least 5 lbs. were used in small non-condensing engines. He had also pointed out that where water power was available, it might be utilized in a manner which it could not be at present, as, instead of factories having to be built in inaccessible, out-of-the-way places, the dynamo machines could be placed there, and connected by wires to sites where the manufactures could be carried on with comfort, and where transport was easy. He had the good fortune to see the arrangements of Sir William Armstrong, at Craigside; there was a fall of water which drove the machine, the wires were led to the house nearly three-quarters of a mile off, and during the day the force was employed to work a saw bench, and at night for illuminating the house. He had not been there since the Swan lights were introduced; but Sir William Armstrong wrote to him a couple of months ago, saying that the lighting had

been much improved since he saw it Sir, William stated that the light was perfect so much resembling day light that, at the time of writing, he had even been obliged to get up and draw the curtains, because there was a thrush outside trying to commit suicide by coming through the window. It appeared that the authorities at Berlin did not know how to classify this new railway; but their putting it down as a one-horse tram car reminded him of a curious classification he heard of not long ago, when he visited the celebrated cavern near Trieste. This was lit by candles, and the landlord of the hotel complained that the electric light had been proposed, but the Prefect objected, citing a resolution which had been passed by the authorities, that neither aluminum, electricity, nor any other smoke-producing means of illumination should be employed. With regard to another mode of using electric force, which had been touched upon in the paper, he might say that he had had all the evening a most agreeable perfume coming from a melon on the table before him, which Dr. Siemens had grown by the sun, aided by electricity; and he had no doubt it would prove as good as other fruits he had tasted from the same source. In this paper they had the opening out of a subject, the importance of which it was difficult to exaggerate. If, by means of electricity, they could practically convey power to a distance, and give it forth when required in anything like a reasonable proportion of the power originally employed, it was perfectly certain that they had thereby a means of utilizing the forces of nature, which now were wasted. All round England they had a sea which ebbed and flowed with varying range, but probably the average would be about 15 feet; and if they could, by means of water mills, utilize that enormous tidal force, and transmit it electrically to centers of population, they must economize the coal now employed for the purpose of motive power, and reserve it for those purposes for which, up to the present time, it would seem that coal was needed, viz.: for metallurgical and other similar purposes. At the same time he by no means despaired of hearing that it was no longer needed directly even for these operations, for it was beginning to appear that electricity was able to do that, in the way of melting refractory materials, which had hitherto been done by the expenditure of fuel. The subject of the paper was so large and important, that he thought it would not be too much to ask the Council of the Society to devote next Wednesday evening to a continuance of the discussion.

Professor Ayrton said the first point which occurred to him on hearing the paper, was in connection with the formula by which Mr. Siemens arrived at the result that the efficiency of electrical transmission ought to reach the maximum when the velocity of the motor was equal to that of the generator; but who went on to say that there seemed to be something wrong in this theoretical conclusion, because it was not borne out by experiment, and the explanation given was the Foucault currents which were set up by induction in the iron. He ventured to think there was another explanation altogether which would account for the formula not according with experimental results, and, indeed, he should not have predicted that the formula would agree with the results. He presumed that the experiments to which they referred were made with dynamo machines, in which the current generated by the machine was used to excite the field magnets. Now, supposing they had two dynamo-electric machines, one drvien by a steam engine, and producing a current, and the other producing work by means of that current, and imagine them running at exactly the same speed, what would be the result? There would be no currrent whatever passing the wire joining them; because, if running at the same speed, the electro-motive force of the generator must be equal and opposite to that of the motor. But if there was even little current passing between the two machines, it was impossible for the second machine to receive power at all, since there could be no magnetization of the field magnets. And yet for the motor to revolve rapidly work must be spent in friction, even if no useful work were given out; hence, it was really the use of dynamo machines which caused the theoretical result to differ from the practical. The machines which ought to be used were either dy-

namo-electric machines with separate exciters, or else magneto-electric machines. For the transmission of power efficiently and economically it was absolutely necessary that magnetization of the field magnets should not be produced by the current passing through the wires joining the two machines. But when such an arrangement as he referred to was carried out, there would be little difference between the theoretical and practical result. It would be found that the economy of the transmission increased as the velocity of the motor more and more approached that of the generator; and when both velocities were extremely high, and nearly equal, the efficiency would approach very nearly to 1. There were various considerations which would bear this out. If you made experiments, as his students had done, with magneto-electric machines as motors, measuring the electric energy put into the magneto-electric machine, and at the same time measuring the amount of work given out by it, you did not find that there was a maximum point after which the efficiency diminished. All the experiments he had seen showed that the efficiency increased with the speed; and he had actually obtained with a very high speed an efficiency of 92 per cent. He thought, on the whole, the conclusions Mr. Siemens had arrived at tended to show what Professor Perry and himself had advanced several times, that they ought to use either magneto-electric machines or dynamo machines, with separate exciters; and, to a certain extent, this conclusion was borne out by practical experience, because he learned that in electric lighting, which was but one mode of transmitting power, it was becoming the practice to use separate exciters for the dynamo machines; and that was the method adopted by Dr. Siemens in the city. As the chairman had pointed out, the great advantage of electricity as a means of transmitting power was not that the friction and leakage inseparable from other methods could not be calculated; but experiments seemed to show that electricity had no mass; that there was no inertia in it; and there was no waste of power in making it go round a corner, as there was with water or any kind of material fluid. In many respects, of course, the flow of electrictity through a wire was like the flow of water through a pipe; the quantity of current was constant, and the electricity lost potential, just as water lost head; but there was this great difference between the two, when you had to make water go round a bend you lost a great deal of power, and the form of the bend made a considerable difference. If you had two or more bends in a pipe, in opposite directions, you lost more power than if there were a continuous curve in the same direction; but this was not so with an electric conductor, since bends made absolutely no difference in the electric resistance of a wire. The chairman had alluded to the great advantage which would result from an enormous quantity of waste power being utilized, and with that he concurred, not so much with regard to the tide, the utilization of which he feared lay in the dim future, in consequence of the great expense of storing the water when the tide rose, but rather with regard to the water power of streams. It was quite lamentable to walk about the neighborhood of Sheffield and see the number of old grindstones which formerly were worked by water power, now lying idle, the grinders having all gone into Sheffield, where they used grindstones worked by steam power, which cost them more; but they saved, on the whole, on account of the expense of transportation. If those streams could be used to work magneto-electric machines, from which the power could be conveyed into the town, and there utilized, it would be an immense advantage. There was another point about electric railways which might not have struck some of those present. At present locomotives weighed from 40 to 60 tons, necessitating very substantial and expensive bridges and permanent way, and it was impossible to make them much lighter, or they would not have sufficient adhesion on the rails to pull a train; you could not much diminish the weight so long as you drove a train by one or two pair of driving wheels. But if you drove the train by nearly all the pairs of wheels, as could easily be done electrically, it might be made comparatively light, and there would be no loss by slip. The great value of the paper lay in its technical character; it was a

laudable example of the application of principles of science to practice, which characterized all the work of the Messrs. Siemens; and if he had ventured to differ a little from some small part of the theoretical considerations advanced, he would conclude by assuring the meeting that no one more highly appreciated its practical bearing.

Mr. J. N. Shoolbred said he had made some experiments on the transmission of power, and was much struck by the remarks of Professor Ayrton on the amount of useful power the formulæ disclosed, and also as to the nature of the machines which, in his opinion, would have to be employed. He agreed with him as to the errors, which had probably arisen from the use of two dynamo machines, one as the generator and the other as the motor. He had himself long seen reason to doubt the ordinary statement that there must be a loss of 50 per cent. in the second machine, and he hoped, by some means or other, they would be able to discover the proper formula. With regard to the two classes of machines, spoken of by Professor Ayrton as the best form of primary machines, either magneto machines or dynamo machines with separate exciters, he thought—especially where the same machines were used for lighting and for transmitting power in the daytime—that dynamo machines would be chiefly employed; but they would generally fall under the condition of having one common exciter, and, consequently, according to Professor Ayrton, about 80 per cent. of the original duty given off might be recovered.

Professor Ayrton wished to explain that the figures he had used, which were quoted in the paper, did not mean that if you gave a certain amount of power to the dynamo-electric machine you could get out 90 per cent. of that in the electric light produced by that machine; it only meant that 90 per cent. of the power given to the machine was reproduced as electric energy. Some of that energy was employed in producing light, but a large portion—often nearly half, or more —was employed in heating the wires or the magnets.

Dr. C. W. Siemens, F. R. S., said he would only make a few remarks that evening, and speak more at length when the discussion was resumed next week. Professor Ayrton had remarked that the dynamo machine would be superseded by the magneto machine, or by a dynamo machine with a separate exciter, and he confessed that he went a long way with him in his argument; indeed, last year he communicated a paper to the Royal Society in which he showed certain defects in the dynamo machine, and suggested certain remedies. The dynamo labored under this defect, that, with an increase of work, the power to overcome the resistance diminished. The current produced by the rotation of the coils in the magnetic field had to excite the coils of the magnet itself, and the current then passed on to the second machine or to the light, to the place where the work was to be performed. Now, if that work should present increased resistance, the machine which had to overcome it should increase in energy, whereas the greater resistance caused a weakening of the current and a falling off in the power of the magnets by which the current was produced, thus causing those fluctuations which were so troublesome in electric lamps, but which, by different arrangements, had been almost overcome, and would be entirely overcome by the aid of further experience. It was quite true that in the city they were working with dynamo machines having separate exciters, but the dynamo machine could be so arranged that a portion only of the current was set aside to excite its own magnet, and if that arrangement were properly applied, he believed all the advantages of a separate exciter could be secured with a single machine. The subject especially before them, however, was the application of electricity to the propulsion of railways and the transmission of power, of which the propulsion of carriages was only one branch. Several other methods by which propulsion could be effected might be mentioned. Only a few days ago he had been in Paris, and had arranged for the construction of a short line of comparatively broad guage, which was to be carried out by the omnibus company of Paris, in connection with the Electrical Exhibition. An ordinary tram car would be run from the Place de la Concorde to the Exhibition, upon rails laid in the usual manner, hav-

ing a suspended conductor along the side of the railway. This conductor would have a little carriage passing along it, in order to transmit the electric current from the suspended wire to the machine, and back through the rails themselves. That arrangement, which was devised by Dr. Werner Siemens, made them independent of partial insulation of the rails upon which the carriage ran, and also independent of the partial insulation of the wheels of one side from the other, leaving the rolling stock very much the same as at present, transferring the current to a separate conductor, something analogous to a single wire telegraph, upon which the contact roller ran and conveyed the current to the machine. Another arrangement by which an ordinary omnibus might be run upon the street would be to have a suspender thrown at intervals from one side of the street to the other, and two wires hanging from these suspenders; allowing contact rollers to run on these two wires, the current could be conveyed to the tram car, and back again to the dynamo machine at the station, without the necessity of running upon rails at all. He merely mentioned this to show that the system was not one which must be carried out in one particular way only, but was capable of very wide modification and extension according to circumstances.

The paper referred to certain applications which he had made of electricity, near Tunbridge Wells, to horticulture, and on the table was a melon which had been produced by the aid of the electric light.

CONTINUOUS GIRDERS.

By F. E. KIDDER, B. C. E.

Written for Van Nostrand's Engineering Magazine.

Having occasion to look into the subject of continuous girders, as applied to building construction, the writer was surprised to find how little has been published on the subject, and how scattered and inconvenient that little is. Thinking, therefore, that a table of formulæ for the more common cases of continuous girders would be very useful and convenient, the writer has prepared the following paper giving the various formulæ, with their derivation, for continuous girders of two and three spans loaded in such ways as often occur in practice. Such of the formulæ as correspond to those given by other writers have been very carefully verified by comparison, and many which could be verified in no other way have been tested by experiments made for the purpose.

The general formulæ for continuous girders of uniform cross section are taken from "Rankine's Civil Engineering," pages 287 and 288.

In these and the subsequent formulæ, the following notation will be adopted:

Let E denote the modulus of elasticity of the material.

F_1 " " shearing force just to right of origin.

F_{-1} " " shearing force just to left of origin.

I " " moment of inertia of the cross section.

l " " length of span to right of origin.

l_1 " " length of span to left of origin.

M " " bending moment at any given section.

M_0 " " bending moment at the origin.

M_1 " " bending moment over support to right of origin.

M_{-1} " " bending moment over support to left of origin.

T_1 " " slope at $x=o$, in span to right of origin.

T_{-1} " " slope at $x=o$, in span to left of origin.

v denote the deflection at any given point.
w " " distributed load per unit of span l.
w_1 " " distributed load per unit of span l_1.
x " " horizontal distance of any given section from the origin.

Let all horizontal distances to the right of origin be positive, and those to the left negative.

Let v and the vertical forces be *positive downwards.*

General formulæ.—The general formulæ for continuous girders, with uniformly distributed loads, given by Rankine are:

$$M=M_0-F_x+m \quad \ldots \quad (1)$$

$$v=T_x-F_q+M_0 n+V \quad \ldots \quad (2)$$

$$F_1=\frac{M_0-M_1+m_1}{l} \quad \ldots \quad (3)$$

$$T=M_0\left(\frac{q_1}{l^2}-\frac{n_1}{l}\right)-\frac{M_1 q_1}{l^2}+\frac{m_1 q_1}{l^2}-\frac{V_1}{l} \quad . \quad (4)$$

$$T_{-1}=M_0\left(\frac{q_{-1}}{l_1^2}-\frac{n_{-1}}{l_1}\right)-\frac{M_{-1}\,q_{-1}}{l_1^2}+\frac{m_{-1}\,q_{-1}}{l_1^2}-\frac{V_{-1}}{l_1} \quad \ldots \quad (5)$$

Expression for the theorem of the three moments

$$\left.\begin{aligned}O=M_0\left(\frac{q_1}{l^2}+\frac{q_{-1}}{l_1^2}-\frac{n_1}{l}-\frac{n_{-1}}{l_1}\right)-\\ \frac{M_1 q_1}{l^2}-\frac{M_{-1}\,q_{-1}}{l_1^2}+\frac{m_1 q_1}{l^2}+\\ \frac{m_{-1}\,q_{-1}}{l_1^2}-\frac{V_1}{l}-\frac{V_{-1}}{l_1}-t.\end{aligned}\right\}\ldots(6)$$

In which the letters m, n, q and V, represent the following quantities:

$$\left.\begin{aligned}
m_1&=\int_0^l\int_0^x w dx^2\\
m_{-1}&=\int_0^{l_1}\int_0^x w_1 dx^2\\
n_1&=\int_0^l\int_0^x \frac{dx^2}{EI}\\
n_{-1}&=\int_0^{l_1}\int_0^x \frac{dx^2}{EI}\\
q_1&=\int_0^l\int_0^x \frac{xdx^2}{EI}\\
q_{-1}&=\int_0^{l_1}\int_0^x \frac{xdx^2}{EI}\\
V_1&=\int_0^l\int_0^x \frac{dx^2}{EI}\int_0^x\int_0^x wdx^2\\
V_{-1}&=\int_0^{l_1}\int_0^x \frac{dx^2}{EI}\int_0^x\int_0^x w_1dx^2.
\end{aligned}\right\}(A)$$

When these letters are used without the subscripts 1 and -1, as in the formulæ for V and M, they should be integrated between the limits x and o instead of l and o. The letter $t=T_1-T_{-1}$, and denotes the tangent of the small angle made by the neutral layers of the two spans with each other. In the cases which we shall consider, $t=o$.

To extend the general formulæ to the case of concentrated loads, let W_1 represent any one of the concentrated loads applied at a distance x_1 from the origin to the right; and W_{-1} any concentrated load applied at a distance x_{-1} from the origin to the left.

Then in the formulæ 1 to 6, inclusive, we must make the following changes:

Instead of $m_1=\int_0^l\int_0^x wdx^2$, put

$$m_1=\int_0^l\int_0^x w\,dx^2+\Sigma W_1(l-x)$$

the summation extending as far as the load only.

Instead of

$$V_1=\int_0^l\int_0^x \frac{dx^2}{EI}\int_0^x\int_0^x wdx^2, \text{ put}$$

$$V_1=\int_0^l\int_0^x \frac{dx^2}{EI}\int_0^x\int_0^x wdx^2+\Sigma W_1\int_{x_1}^l\int_{x_1}^x\frac{(x-x_1)dx}{EI};$$

and make the corresponding changes in m_{-1} and V_{-1}. n and q will remain as before. (B)*

We will now apply the general formulæ just given to the following particular cases, in all of which the girder is supposed to be of uniform cross section.

* For these values the writer is indebted to Prof. Gaetano Lanza, of the Massachusetts Institute of Technology.

Case I.

Continuous girder of two spans, with uniformly distributed load.

Let l_1 = length of span AB.
l = " " " BC.
w = load per linear unit of BC.
w_1 = " " " " " AB.
R_1, R_2, R_3 = the reactions at the supports A, B and C, respectively.

Take origin of co-ordinates at B, and denote the bending moment at that point by M_B, or $M_0 = M_B$.

As there can be no bending moment at the supports A and C, $M_1 = M_{-1} = O$, also $t = o$.

Shearing force just to left of B =

$$F_{-1} = \frac{M_B + m_{-1}}{l_1} = \frac{w_1 l_1}{2} + \frac{wl^3 + w_1 l_1^3}{8l_1(l+l_1)}$$

Shearing force just to right of B =

$$F_1 = \frac{M_B + m_1}{l} = \frac{wl}{2} + \frac{wl^3 + w_1 l_1^3}{8l(l+l_1)}$$

$$R_2 = F_1 + F_{-1}$$

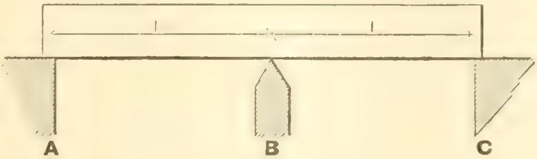
Shearing force at C =

$$R_3 = \frac{wl}{2} - \frac{wl^3 + w_1 l_1^3}{8l(l+l_1)} \quad . \quad . \quad . \quad . \quad (9)$$

Shearing force at distance x from A

$$= -R_1 + w_1 x.$$

Shearing force at distance x from C



$$m_1 = \int_0^l \int_0^x w dx^2 \frac{wl^2}{2}, \qquad m_{-1} = \frac{w_1 l_1^2}{2}$$

$$n_1 = \int_0^l \int_0^x \frac{dx^2}{EI} = \frac{l^2}{2EI}; \qquad n_{-1} = \frac{l_1^2}{2EI}$$

$$q_1 = \int_0^l \int_0^x \frac{x dx^2}{EI} = \frac{l^3}{6EI}; \qquad q_{-1} = \frac{l_1^3}{6EI}$$

$$V_1 = \int_0^l \int_0^x \frac{dx^2}{EI} \int_0^x \int_0^x w dx^2 = \frac{wl^4}{24EI};$$

$$V_{-1} = \frac{w_1 l_1^4}{24EI}.$$

Substituting these values in eq. 6 we have

$$O = M_B \left(\frac{l}{6EI} + \frac{l_1}{6EI} - \frac{l}{2EI} - \frac{l_1}{2EI} \right) + \frac{wl^3}{12EI} + \frac{w_1 l_1^3}{12EI} - \frac{wl^3}{24EI} - \frac{w_1 l_1^3}{24EI};$$

and by combining and eliminating we obtain the expression

$$M_B = \frac{wl^3 + w_1 l_1^3}{8(l+l_1)} \quad . \quad . \quad . \quad . \quad (7)$$

From equation 3 we obtain:

Shearing force at A (taking origin at that point) =

$$R_1 = \frac{-M_B + m_{-1}}{l_1} = \frac{w_1 l_1}{2} - \frac{wl^3 + w_1 l_1^3}{8l_1(l+l_1)} \quad . \quad (8)$$

$$= -R_3 + wx.$$

From eq. 1 we find:

Bending moment at distance x from A =

$$M = -R_1 x + \frac{w_1 x^2}{2} \quad . \quad . \quad . \quad (10)$$

Bending moment at distance x from B =

$$M = M_B - F_1 x \frac{wx^2}{2} \quad . \quad . \quad . \quad (11)$$

From eq. 4 we find:

Slope at A =

$$T_{-1} = -\frac{M_B l_1}{6EI} + \frac{w_1 l_1^3}{12EI} - \frac{w_1 l_1^3}{24EI} = -\frac{M_B l_1}{6EI} + \frac{w_1 l_1^3}{24EI} \quad . \quad . \quad . \quad . \quad (12)$$

Slope at B, in span BC =

$$T_1 = M_B \left(\frac{l}{6EI} - \frac{l}{2EI} \right) + \frac{wl^3}{12EI} - \frac{wl^3}{24EI} = -\frac{M_B l}{3EI} + \frac{wl^3}{24EI} \quad . \quad . \quad (13)$$

From eq. 2:

Deflection in span AB at distance x from A =

$$v = T_{-1} x - \frac{R_1 x^3}{6EI} + \frac{w_1 x^4}{24EI} \quad . \quad . \quad (14)$$

Deflection in span BC at distance x from B =

$$v=T_1x-\frac{F_1x^3}{6EI}+\frac{M_Bx^2}{2EI}+\frac{wx^4}{24EI} \quad . \; . \; . \; (15)$$

In practice both spans are generally loaded alike, so that $w=w_1$, which somewhat simplifies the above formulæ.

Example I.—*Given a continuous girder of two equal spans, with a distributed load of w lbs. per linear unit over each; to find the reactions of the supports, the greatest bending moment and the deflections.*—First find the bending moment M_B. This we can obtain directly from eq. 7, by making $w=w_1$, and $l=l_1$. Making these substitutions we have

$$M_B=\frac{wl^2}{8} \quad . \; . \; . \; . \; (16)$$

Making the same substitutions in equations 8 and 9, we have

$$R_1=R_3=\tfrac{3}{8}\,wl \quad . \; . \; . \; . \; (17)$$

$$R_2=\tfrac{5}{4}\,wl \quad . \; . \; . \; . \; . \; . \; (18)$$

Deflection at distance x from A or C=

$$v=\frac{wl^3x}{48EI}-\frac{wlx^3}{16EI}+\frac{wx^4}{24EI}=$$

$$\frac{w}{48EI}(l^3x-3lx^3+2x^4) \quad . \; . \; (21)$$

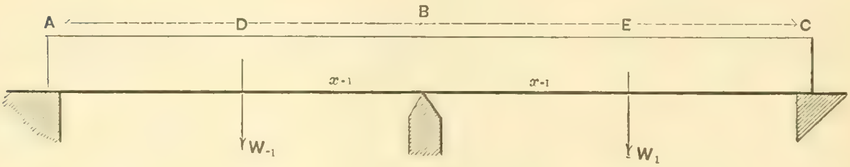
The deflection is greatest when $x=$ .421535 l; and hence the greatest deflection in either span =

$$v=.005416\frac{wl^4}{EI} \quad . \; . \; . \; . \; (22)$$

If we put eq. 19 equal to zero, we shall be able to deduce the value of x for which the bending moment is zero, or, as this point is the point of inflection, to determine the distance of that point from the end. Performing the operation, we find that when $M=o$, $x=\frac{3}{4}l$, hence the points of inflection are at $\frac{3}{4}$ the span from either abutment.

Case II.

Continuous girder of two spans, with both distributed and concentrated loads:



Bending moment at distance x from A or C =

$$M=-R_1x+\frac{wx^2}{2}=-\tfrac{3}{8}wlx+\frac{wx^2}{2} \quad . \; . \; . \; (19)$$

If we differentiate this expression and put the first coefficient equal to zero, we have

$$o=-\tfrac{3}{8}wl+wx;\ \text{or}\ x=\tfrac{3}{8}l$$

which is the value of x for which the bending moment in either span is a maximum. Substituting this value for x, we have:

Greatest bending moment in either span =

$$M=-\frac{9}{128}wl^2 \quad . \; . \; . \; . \; (20)$$

The greatest bending moment in the girder is therefore over the middle support, and equals M_B.

Slope at A, from eq. 12, =

$$T=\frac{wl^3}{48EI}.$$

Let l =length of span BC.
" l_1 = " " " AB.
" w_1 =the load per linear unit of AB.
" w = " " " " " " BC.
" W_1 =concentrated load on BC at distance x_1 from B.
" W_{-1}=concentrated load on AB at distance x_{-1} from B.
" R_1, R_2, R_3=the reactions at the supports A,B and C respectively.

Take origin of co-ordinates at B, then $t=o$; $M_0=M_B$; $M_1=M_{-1}=o$; and from A and B

$$m_1=\int_0^l\int_0^x wdx^2+W_1(l-x_1)=$$

$$\frac{wl^2}{2}+W_1(l-x_1);\ m_{-1}=\frac{w_1l_1^2}{2}+W_{-1}(l-x_{-1}).$$

$$n_1=\int_0^l\int_0^x\frac{dx^2}{EI}=\frac{l^2}{2EI};\qquad n_{-1}=\frac{l_1^2}{2EI}.$$

$$q_1=\int_0^l\int_0^x\frac{xdx^2}{EI}=\frac{l^3}{6EI};\qquad q_{-1}=\frac{l_1^3}{6EI}.$$

$$V_1=\int_0^l\int_0^x\frac{dx^2}{EI}\int_0^x\int_0^x w\,dx^2+\frac{W_1}{EI}$$

$$\int_{x_1}^l\int_{x_1}^x(x-x_1)dx^2=\frac{wl^4}{24}+\frac{W_1(l-x_1)^3}{6EI}.$$

$$V_{-1}=\frac{w_1l_1^4}{24EI}+\frac{W_{-1}(l_1-x_{-1})^3}{6EI}.$$

Substituting these values in eq. 6, we have

$$O=M_B\left(\frac{l}{6EI}-\frac{l}{2EI}+\frac{l_1}{6EI}-\frac{l_1}{2EI}\right)+$$
$$\frac{wl^3}{12EI}+\frac{w_1l_1^3}{12EI}+\frac{W_1l(l-x_1)}{6EI}+$$
$$\frac{W_{-1}l_1(l_1-x_{-1})}{6EI}-\frac{wl^3}{24EI}-\frac{w_1l_1^3}{24EI}-$$
$$\frac{W_1l(l-x_1)^3}{6EI}-\frac{W_{-1}l_1(l_1-x_{-1})^3}{6EI};$$

from which we obtain

$$\left.\begin{aligned}M_B=&\frac{wl^3+w_1l_1^3}{8(l+l_1)}+\\&\frac{W_1l(l-x_1)+W_{-1}l_1(l_1-x_{-1})}{2(l+l_1)}-\\&\frac{W_1(l-x_1)^3}{2l(l+l_1)}-\frac{W_{-1}(l-x_{-1})}{2l_1(l+l_1)}.\end{aligned}\right\}\quad(23)$$

From eq. 3 we find:

Shearing force at A (taking origin at A) =

$$R_1=\frac{-M_B+\frac{w_1l_1}{2}+W_{-1}(l_1-x_{-1})}{l_1}.\quad(24)$$

Shearing force just to left of B =

$$F_{-1}=\frac{M_B+\frac{w_1l_1^2}{2}+W_{-1}(l_1-x_1)}{l_1}.$$

Shearing force just to right of B =

$$F_1=\frac{M_B+\frac{wl^2}{2}+W_1(l-x_1)}{l}.$$

$R_2=F_{-1}+F_1$.

Shearing force at C =

$$R_3=\frac{-M_B+\frac{wl^2}{2}+W_1(l-x_1)}{l}\quad.\quad.\quad.\quad(25)$$

Shearing force in section AD at distance x from A

$$=-R_1+w_1x.$$

Shearing force in section DB at distance x from A

$$=-R_1+w_1x+W_{-1}.$$

Shearing force in section BE at distance x from B

$$=-F_1+wx.$$

Shearing force in section EC at distance x from B

$$=-F_1+wx+W_1.$$

From eq. 1, we obtain:

Bending moment in section AD at distance x from A

$$=-R_1x+\frac{w_1x^2}{2}.$$

Bending moment in section DB at distance x from A

$$=-R_1x+\frac{w_1x^2}{2}+W_{-1}[x-(l_1-x_{-1})].$$

Bending moment in section BE at distance x from B

$$=M_B-F_1x+\frac{wx^2}{2}.$$

Bending moment in section EC at distance x from B

$$=M_B-F_1x+\frac{wx^2}{2}+W_1(x-x_1).$$

From eq. 4:

Slope at A =

$$T_{-1}=-\frac{M_Bl_1}{6EI}+\frac{w_1l_1^3}{6EI}+\frac{W_{-1}l_1(l_1-x_{-1})}{6EI}-$$
$$\frac{w_1l_1^3}{24EI}-\frac{W_{-1}(l_1-x_{-1})^3}{6l_1EI}.$$

Slope at B, in span BC =

$$T_1=-\tfrac{1}{3}\frac{M_Bl}{EI}+\frac{wl^3}{6EI}+$$
$$\frac{W_1l(l-x_1)}{6EI}-\frac{wl^3}{24EI}-\frac{W_1(l-x_1)^3}{6lEI}.$$

From eq. 2:

Deflection in section AD at distance x from A =

$$v=T_{-1}x-\frac{R_1x^3}{6EI}+\frac{w_1x^4}{24EI}.$$

Deflection in section DB at distance x from A =

$$v=T_{-1}x-\frac{R_1x^3}{6EI}+\frac{w_1x^4}{24EI}+\frac{W_1(x-x_1)^3}{6EI}.$$

Deflection in section BE at distance x from B =

$$v=T_1x-\frac{F_1x^3}{6EI}+\frac{M_Bx^2}{2EI}+\frac{wx^4}{24EI}.$$

Deflection in section EC at distance x from B =

$$v = T_1 x - \frac{F_1 x^3}{6EI} + \frac{M_B x^2}{2EI} + \frac{w x^4}{24EI} + \frac{W(x - x_1)^3}{6EI}.$$

The position of the point of greatest deflection will depend upon the proportion of the loads and spans, and must be found for each separate case.

Example II. — *Given a continuous girder of two equal spans, loaded at the center of the right span with a load of* W_1 *lbs., and at the center of the left span with* W_{-1} *lbs; and having no distributed load; to find the reactions of the supports, the greatest bending moments, and the deflections.*—In this example, $l = l_1$, $w_1 = w = o$, and $x_1 = x_{-1} = \frac{l}{2}$. Making these substitutions in the formulæ of Case II we obtain:

Bending moment over center support =

$$M_B = \tfrac{3}{32} l (W_1 + W_{-1}) \quad . \quad . \quad (26)$$

$$R_1 = \frac{13W_{-1} - 3W_1}{32} \quad . \quad . \quad . \quad . \quad (27)$$

$$R_2 = \tfrac{11}{16}(W_1 + W_{-1}) \quad . \quad . \quad . \quad . \quad (28)$$

$$R_3 = \frac{13W_1 - 3W_{-1}}{32} \quad . \quad . \quad . \quad . \quad (29)$$

Bending moment in section AD at distance x from A =

$$M = \frac{(3W_1 - 13W_{-1})x}{32}$$

Bending moment in section DB at distance x from A =

$$M = W_{-1}\left(x - \frac{l}{2}\right) - \frac{(13W_{-1} - 3W_1)x}{32}.$$

Bending moment in section EC at distance x from B =

$$M = \tfrac{3}{32}(W_1 + W_{-1})l - \tfrac{3}{32}(W_1 + W_{-1})x - \frac{W_1 x}{2} - W_1\left(x - \frac{l}{2}\right).$$

Greatest bending moment in right span, equals bending moment at center =

$$M = \frac{(3W_{-1} - 13W_1)l}{64} \quad . \quad . \quad (31)$$

Greatest bending moment in girder is therefore M_B (eq. 26).

Slope at A =

$$T_{-1} = \frac{(3W_{-1} - W_1)l^2}{64EI}.$$

Deflection at center of left span =

$$v = \frac{(23W_{-1} - 9W_1)l^3}{1536EI} \quad . \quad . \quad . \quad (32)$$

Slope at B in span BC =

$$T_1 = \frac{(W_1 - W_{-1})l^2}{32EI} = o, \text{ when } W_1 = W_{-1}.$$

Deflection at center of right span =

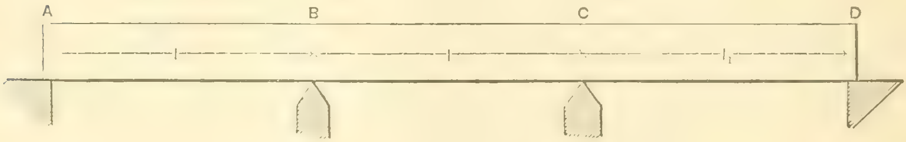
$$v = \frac{(23W_1 - 9W_{-1})l^3}{1536EI} \quad . \quad . \quad . \quad (33)$$

There are two special cases under this example, mentioned by Moseley, which deserve pointing out.

First, when $W_{-1} = 3W_1$, the right span of the girder will be horizontal; and second, when $3W_{-1} = 13W_1$ the reaction of the right abutment will be zero.

Case III.

Continuous girder of three spans with uniformly distributed load only.



Greatest bending moment in left span equals bending moment at center =

$$M = \frac{(3W_1 - 13W_{-1})l}{64} \quad . \quad . \quad . \quad . \quad (30)$$

Bending moment in section BE at distance x from B =

$$M = \tfrac{3}{32}(W_1 + W_{-1})l - \tfrac{3}{32}(W_1 + W_{-1})x - \frac{W_1 x}{2}.$$

Let l_1 = length of span AB and CD.
" l = " " " BC.
" w = the load per linear unit of BC.
" w_1 = " " " " " " AB, and CD.
" R_1, R_2, R_3, R_4 = the reactions of the supports at A, B, C and D respectively.

First take origin at B, then $t = o$; $M_0 = M_B$; $M_{-1} = o$; $M_1 = M$;

$$m_1=\frac{wl^2}{2};\quad m_{-1}=\frac{w_1l_1^2}{2}$$

$$n_1=\frac{l^2}{2EI};\quad n_{-1}=\frac{l_1^2}{2EI}$$

$$q_1=\frac{l^3}{6EI};\quad q_{-1}=\frac{l_1^3}{6EI}$$

$$V_1=\frac{wl^4}{24EI};\quad V_{-1}=\frac{w_1l_1^4}{24EI};$$

and

$$o=M_B\left(\frac{l}{6EI}+\frac{l_1}{6EI}-\frac{l}{2EI}-\frac{l_1}{2EI}\right)-\frac{M_C\,l}{6EI}+\frac{wl^3}{12EI}+\frac{w_1l_1^3}{12EI}-\frac{wl^3}{24EI}-\frac{w_1l_1^3}{24EI},$$

or $\quad 8M_B(l+l')+4M_C\,l=wl^3+w_1l_1^3.$

As the girder is symmetrically loaded and supported on either side of the center, M_C must equal M_B, hence

$$M_B=\frac{wl^3+w_1l_1^3}{4(3l+2l')}\quad . \quad . \quad . \quad . \quad (34)$$

From eq. 3 we obtain:

Shearing force at A or B (origin at A) =

$$R_1=R_4=\frac{-M_B+\frac{w_1l_1^2}{2}}{l_1}=\frac{w_1l_1}{2}-\frac{wl^3+w_1l_1^3}{4l_1(3l+2l')}\quad . \quad . \quad . \quad (35)$$

Shearing force just to left of B, or right of C =

$$F_{-1}=\frac{M_B+\frac{w_1l_1^2}{2}}{l_1}=\frac{w_1l_1}{2}+\frac{wl^3+w_1l_1^3}{4l_1(3l+2l')}.$$

Shearing force just to right of B, or left of C =

$$F_1=\frac{M_B-M_C+\frac{wl^2}{2}}{l}=\frac{wl}{2}$$

$$R_2=R_3=F_{-1}+F_1=\frac{wl+w_1l_1}{2}+\frac{wl^3+w_1l_1^3}{4l_1(3l-2l_1)}\quad . \quad . \quad . \quad . \quad (36)$$

Shearing force in span AB or CD at distance x from A or D

$$=-R_1+wx.$$

Shearing force in middle span at distance x from B or C

$$=-F_1+wx=-\frac{wl}{2}+wx.$$

From eq. 1:

Bending moment in span AB or CD at distance x from A or D =

$$M=-R_1x+\frac{w_1x^2}{2}.$$

Bending moment in middle span at distance x from B or C =

$$M=M_B-F_1x+\frac{wx^2}{2}.$$

The greatest bending moment in middle span is when $x=\frac{l}{2}$, or

$$M=M_B-\frac{wl^2}{8}.$$

The position of the point of greatest bending moment in the end spans depends upon the proportions of w and w_1 and l and l_1 to each other. When the spans and loads are equal the greatest bending moment is at a distance $x=\frac{2}{5}l$ from A or D. The greatest bending moment in the girder is $M_B=M_C$.

From eq. 4:

Slope at A =

$$T_{-1}=\frac{-M_Bl_1}{6EI}+\frac{w_1l_1^3}{12EI}-\frac{w_1l_1^3}{24EI}.$$

Slope at B, in span BC =

$$=T_1=-\frac{1}{3}\frac{M_Bl}{EI}-\frac{M_Bl}{6EI}+\frac{wl^3}{12EI}-\frac{wl^3}{24EI}-\frac{M_Bl}{2EI}+\frac{wl^3}{24EI}.$$

From eq. 2:

Deflection in span AB or CD at distance x from A or D =

$$v=T_{-1}x-\frac{R_1x^3}{6EI}+\frac{wx^4}{24EI}.$$

Deflection in middle span at distance x from B or C =

$$v=T_1x-\frac{F_1x^3}{6EI}+\frac{M_Bx^2}{2EI}+\frac{wx^4}{24EI}.$$

Example III. — *Given a continuous girder of three equal spans, loaded uniformly over its whole length with w lbs. per linear unit; to find the reactions of the supports, the bending moments and the deflections in the different spans.*— Here $w=w_1$, and $l=l_1$, and making these substitutions in the equations of Case III, we have

$$M_B=\frac{wl^2}{10}\quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (37)$$

$$R_1=R_4=\tfrac{2}{5}wl \quad . \quad . \quad . \quad . \quad . \quad (38)$$

$$R_2=R_3=\tfrac{11}{10}wl \quad . \quad . \quad . \quad . \quad . \quad (39)$$

Bending moment in span AB or CD at distance x from A or D =

$$M=-\tfrac{2}{5}wlx+\frac{wx^2}{2}.$$

Greatest bending moment in end spans is at the distance $\frac{2}{5}l$ from the abutments, or

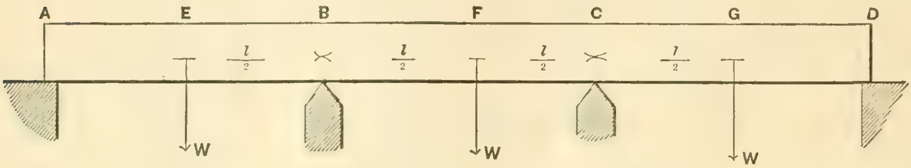
$$M=-\tfrac{2}{25}wl^2 \quad . \quad . \quad . \quad . \quad (40)$$

Maximum deflection in span BC equals deflection at the center =

$$v=\frac{wl^4}{1920EI} \quad . \quad . \quad . \quad . \quad . \quad (45)$$

CASE IV.

Continuous girder of three equal spans, with a concentrated load, W, *at the center of each span, and a distributed load of* w *lbs. per linear unit over its whole length:*



Bending moment in middle span at distance x from B or C =

$$M=\frac{wl^2}{10}-\frac{wlx}{2}+\frac{wx^2}{2}.$$

The greatest bending moment in middle span is where $x=\frac{l}{2}$, and equals

$$M=-\frac{wl^2}{40} \quad . \quad . \quad . \quad . \quad (41)$$

Hence the greatest bending moment in the girder is at B and C, and equals

$$\frac{wl^2}{10}.$$

Slope at A =

$$T_{-1}=\frac{wl^3}{40EI}.$$

Deflection in span AB or CD at distance x from A or D =

$$v=\frac{wl^3x}{40EI}-\frac{wx^3l}{15EI}+\frac{wx^4}{24EI} \quad . \quad . \quad . \quad (42)$$

This is greatest when $x=.44604\,l$, or maximum deflection in span AB or CD=

$$v=.006884\frac{wl^4}{EI} \quad . \quad . \quad . \quad . \quad . \quad (43)$$

Slope at B, in span BC =

$$T_1=-\frac{1}{120}\cdot\frac{wl^3}{EI}.$$

Deflection in span BC at distance x from B or C =

$$v=-\frac{wl^3x}{120EI}-\frac{wlx^3}{12EI}+\frac{wl^2x^2}{20EI}+\frac{wx^4}{24EI}. (44)$$

Let l = length of each span.

" w = distributed load per linear unit over each span.

" W = concentrated load at center of each span.

" $R_1=R_4$, $R_2=R_3$, denote the reactions of the supports at A, D, B and C respectively.

Take origin at B, then $t=o$; $M_0=M_E$; $M_1=M_C=M_B$;

$$m_1=m_{-1}=\frac{wl^2}{2}+\frac{Wl}{2};\ n_1=n_{-1}=\frac{l^2}{2EI};$$

$$q_1=q_{-1}=\frac{l^3}{6EI};\ V_1=V_{-1}=\frac{wl^4}{24EI}+\frac{Wl^3}{48EI};$$

and

$$o=-\tfrac{2}{3}\frac{M_Bl^3}{EI}-\frac{M_Bl^3}{6EI}+\frac{wl^5}{6EI}+\frac{Wl^4}{6EI}-\frac{wl^5}{12EI}-\frac{Wl^4}{24EI};$$

or

$$M_B=\frac{wl^2}{10}+\frac{3}{20}Wl \quad . \quad . \quad . \quad (46)$$

Shearing force at A or D =

$$R_1=R_4=\frac{-M_B+m_1}{l}=\frac{2}{5}wl+\frac{7}{20}W \quad . \quad (47)$$

Shearing force just to left of B, or right of C =

$$F_{-1}=\frac{M_B+\frac{wl^2}{2}+\frac{Wl}{2}}{l}=\tfrac{3}{5}wl^2+\tfrac{13}{20}Wl.$$

Shearing force just to right of B, or left of C =

$$F_1=\frac{M_B-M_C+m_1}{l}=\frac{wl}{2}+\frac{W}{2}$$

$$R_2 = R_3 = F_{-1} + F_1 = \tfrac{11}{10} wl + \tfrac{23}{20} W \quad . \quad . \quad (48)$$

Shearing force in section AE at distance x from A

$$= -R_1 + wx.$$

Shearing force in section EB at distance x from A

$$= -R_1 + wx + W.$$

Shearing force in section BF at distance x from B

$$= -F_1 + wx.$$

Shearing force in section FC at distance x from B

$$= -F_1 + wx + W.$$

Bending moment in section AE at distance x from A

$$= -R_1 x + \frac{wx^2}{2}.$$

Bending moment in section EB at distance x from A

$$= -R_1 x + \frac{wx^2}{2} + W\left(x - \frac{l}{2}\right).$$

Bending moment in section BF at distance x from B

$$= M_B - F_1 x + \frac{wx^2}{2}.$$

The greatest bending moment in middle span is when $x = \frac{l}{2}$, hence

$$M = -\frac{wl^2}{40} - \frac{Wl}{10} \quad . \quad . \quad . \quad . \quad (49)$$

Bending moment at center of span AB or CD (not necessarily the greatest bending moment in span) =

$$M = -\tfrac{11}{40} wl^2 - \tfrac{7}{20} Wl \quad . \quad . \quad (50)$$

Slope at A =

$$T_{-1} = -\frac{M_B l}{6EI} + \frac{wl^3}{12EI} + \frac{Wl^2}{12EI} - \frac{wl^3}{24EI} - \frac{Wl^2}{48EI}$$

$$= \frac{wl^3}{40EI} + \tfrac{3}{80} \cdot \frac{Wl^2}{EI}.$$

Deflection in section AE at distance x from A =

$$v = T_{-1} x - \frac{R_1 x^3}{6EI} + \frac{wx^4}{24EI} = \frac{w}{120EI}$$

$$(3l^3 x - 8x^3 l + 5x^4) + \frac{W}{120EI}\left(\frac{9l^2 x}{2} - 7x^3\right) \; (51)$$

Deflection in section EB at distance x from A =

$$v = T_{-1} x - \frac{R_1 x^3}{6EI} + \frac{wx^4}{24EI} + \frac{W\left(x - \frac{l}{2}\right)^3}{6EI}$$

$$= \frac{w}{120EI}(3l^3 x - 8x^3 l + 5x^4) +$$

$$\frac{W}{120EI}\left\{\frac{9l^2 x}{2} - 7x^3 + 20\left(x - \frac{l}{2}\right)^3\right\} (51a)$$

Deflection at center of end spans =

$$v = \frac{13}{1920} \cdot \frac{wl^4}{EI} + \frac{11}{960} \cdot \frac{Wl^3}{EI} \quad . \quad (52)$$

Slope at B, in span BC =

$$T_1 = -\frac{1}{3}\frac{M_B l}{EI} - \frac{M_C l}{6EI} + \frac{wl^3}{12EI}$$

$$+ \frac{Wl^2}{12EI} - \frac{wl^3}{24EI} - \frac{Wl^2}{48EI};$$

$$= -\frac{1}{120} \cdot \frac{wl^3}{EI} - \frac{1}{80} \cdot \frac{Wl^2}{EI}$$

Deflection in section BF at distance x from B =

$$v = T_1 x - \frac{F_1 x^3}{6EI} + \frac{M_B x^2}{2EI} + \frac{wx^4}{24EI}$$

$$= \frac{w}{120EI}(5x^4 - l^3 x + 6l^2 x^2 - 10lx^3)$$

$$+ \frac{W}{120EI}(9lx^2 - \tfrac{3}{2} l^2 x - 10x^3) \; . \; (53)$$

Deflection at center of middle span =

$$v = \frac{wl^4}{1920EI} + \frac{Wl^3}{480EI} \quad . \quad . \quad (54)$$

The above four cases are the principal cases met with in building construction, and any other case can be solved in a similar way without much difficulty. For convenience in using these formulæ, we will give a summary of those most frequently needed in actual practice.

SUMMARY OF THE MORE USEFUL FORMULÆ.

I. *Continuous girders of two spans.*

a. Uniformly distributed load of w lbs. per linear unit over both spans.

Length of left span $= l_1$; length of right span $= l$.

Reaction of left abutment=

$$R_1 = \frac{w}{2}\left\{ l_1 - \frac{l^3 + l_1^3}{4l_1(l+l_1)} \right\} \quad . \quad . \quad (55)$$

Reaction of middle support=

$$R_2 = w(l_1 + l) - R_1 - R_3.$$

Reaction of right abutment=

$$R_3 = \frac{w}{2}\left\{ l - \frac{l^3 + l_1^3}{4l(l+l_1)} \right\} \quad . \quad . \quad (56)$$

Greatest bending moment in girders is at the middle point of support, and equals

$$M = \frac{wl^3 + wl_1^3}{8(l+l_1)} \quad . \quad . \quad . \quad . \quad (57)$$

When $l = l_1$, greatest deflection in either span=

$$v = .005416 \frac{wl_4}{EI} \quad . \quad . \quad . \quad . \quad (22)$$

b. Concentrated load at center of left span of W_{-1} lbs., and at center of right span of W_1 lbs.

Length of either span=l.

Reaction of left abutment=

$$R_1 = \frac{13W_{-1} - 3W_1}{32} \quad . \quad . \quad (27)$$

Reaction of middle support=

$$R_2 = \tfrac{11}{16}(W_1 + W_{-1}) \quad . \quad . \quad (28)$$

Reaction of right abutment=

$$R_3 = \frac{13W_1 - 3W_{-1}}{32} \quad . \quad . \quad (29)$$

Greatest bending moment in the girder is at the middle support, and equals—

$$M = \tfrac{3}{32} l (W_1 + W_{-1}) \quad . \quad . \quad (26)$$

Deflection at center of left span=

$$v = \frac{(23W_{-1} - 9W_1)l^3}{1536EI} \quad . \quad (32)$$

Deflection at center of right span=

$$v = \frac{(23W_1 - 9W_{-1})l^3}{1536EI} \quad . \quad . \quad (33)$$

When there is both a distributed and a concentrated load the reactions of the supports, bending moments, and deflections, will be the sum of those for a distributed load and those for a concentrated load, as shown by the formulæ of Cases II. and IV.

II. *Continuous girder of three spans:*

a. Uniformly distributed load of w lbs. per linear unit over each span.

Length of each end span $= l_1$; length of middle span$=l$.

Reaction of either abutment=

$$R_2 = R_4 = \frac{w}{2}\left\{ l - \frac{l^3 + l_1^3}{2l_1(3l + 2l_1)} \right\} \quad . \quad (58)$$

Reaction of either central support=

$$R_3 = R_3 = \frac{w}{2}\left\{ (l + l_1) + \frac{l^3 + l_1^3}{2l_1(3l + 2l_1)} \right\} \quad (59)$$

Greatest bending moment in the girder is at either of the central supports, and equals

$$M = \frac{wl^3 + wl_1^3}{4(3l + 2l_1)} \quad . \quad . \quad . \quad . \quad (60)$$

When $l = l_1$,

Deflection at center of middle span=

$$v = \frac{wl^4}{1920EI} \quad . \quad . \quad . \quad . \quad (45)$$

Greatest deflection in end spans=

$$v = .006884 \frac{wl^4}{EI} \quad . \quad . \quad . \quad (43)$$

b. Concentrated load of W lbs. at center of each span.

Length of each span=l.

Reaction of either abutment=

$$R_1 = R_4 = \tfrac{7}{20} W \quad . \quad . \quad . \quad (61)$$

Reaction of either central support=

$$R_2 = R_3 = \tfrac{23}{20} W \quad . \quad . \quad . \quad (62)$$

Greatest bending moment in the girder is at either of the central supports, and equals

$$M = \tfrac{3}{20} Wl \quad . \quad . \quad . \quad . \quad . \quad (63)$$

Deflection at center of middle span=

$$v = \frac{Wl^3}{480EI} \quad . \quad . \quad . \quad (64)$$

Deflection at center of end spans=

$$v = \frac{11}{960} \cdot \frac{Wl^3}{EI} \quad . \quad . \quad . \quad (65)$$

Formulæ 55, 56, 57, 58, 59, 60 and 61 are obtained from 8, 9, 7, 35, 36, 34 and 47, respectively, by making $w_1 = w$. Formulæ 61, 62, 63, 64 and 65 are obtained from 47, 48, 46, 54 and 52, respectively, by making $w = o$.

VERIFICATION OF FORMULÆ.

Formulæ 28, 46 and 63 were tested by loading a small steel beam so as to fulfill the condition of the formulæ, and measuring the reactions of the support by means of a spring balance, which was used for the support.

The results obtained from several tests did not vary more than one-half of one per cent. from the values given by the formulæ.

Formulæ 32, 33, 64 and 65 were tested by measuring the deflections of a steel bar $\frac{1}{4}$ inch square, supported on knife edges 12 inches apart, and loaded at the centers of the spans with loads varying from 5 to 25 lbs., and comparing them with the deflection of a beam, cut from the same bar, supported at each end, and loaded with the same loads as the continuous beam, the span being also 12 inches.

The greatest difference between the actual deflections and those given by the formulæ was $7\frac{1}{2}$ per cent., while several values agreed exactly, although it was difficult to arrange the experiments so as to have all of the conditions perfectly fulfilled. We think, however, that these experiments are sufficient to prove the truth of the theory of continuous girders, as applied to small beams at least, and also the accuracy of the formulæ.

For those who care to compare the formulæ contained in this paper with such as can be found elsewhere, we will state that formulæ 7 and 8 agree respectively with formulæ 65 and 66, of "Wheeler's Treatise on Civil Engineering," prepared for the use of the cadets at West Point; formulæ 19, 21, 38, 39, 42 and 44 agree with formula 162, 173, 188, 189, 173 and 187 of "Stoney's Theory of Strains," edition of 1873; and formula 22 is the same as formula 560 of "Moseley's Engineering and Architecture," edited by Mahan.

THE LATEST ASPECT OF THE BRAKE QUESTION.

From "The Engineer."

We told our readers that it was rumored that a very important step was about to be taken by the London and Northwestern Railway Company. According to the reports which have reached us, that company has decided to adopt a new system of continuous brake, and it is hinted that its example will be followed by other companies, so that the carriages and engines of any one line can run over other roads; and trains may be made up of the coaches of all the companies without interfering with the action of the brakes. This proposal contemplates the expenditure of a great deal of money; and the position of the companies is so important, that whatever brake they adopt in common is pretty certain to be extensively, if not universally, adopted, to the exclusion of all others by the remaining railway companies of the United Kingdom. It is therefore of the last importance to the future of the railway system, that if the rumor be true and a selection is to be made, it should be the best possible; and that it should be made under circumstances at once the most favorable, to the rejection of what is bad, weak, or defective, and most likely to secure the adoption of that brake which is the most trustworthy and efficient. A mistake committed now might cause a very prejudicial effect for years to come in the matter of dividends. Let us consider what are the actual conditions obtaining.

The movement appears to have originated with the London and Northwestern Railway Company. The Clark and Webb brake, after being patched up and modified time and again, is now moribund. It has almost invariably been found useless when it was wanted; and the recent accident on the North London line may be said to have given it the *coup de grace*. It has been condemned long ago in the strongest terms by the Board of Trade; and the "emergency brake," of the London and Northwestern Railway, has been the subject for a good many pleasantries among railway men. Mr. Moon has, nevertheless, told the shareholders, over and over again, that they had got an admirable brake, and this at the time that

the said brake was indirectly causing a good deal of destruction of their property, and bringing about annoying claims for compensation. If any of our readers fancy that we are drawing an exaggerated picture, he has but to turn to the Board of Trade reports to see that we have said not nearly so much in condemnation of the system as it deserves. In the selection of the new system, Mr. Moon and Mr. Webb will no doubt have a voice, and a very important and even authoritative voice, too. But may we not ask if either one gentleman or the other is qualified to make a selection? Mr. Moon is the chairman of the company, and is not an engineer; but even a chairman has ample opportunities of knowing what the performance of the mechanical elements of the system which he controls is like. Mr. Moon has either been unable or unwilling to learn what practice with the Clark and Webb brake had to teach; and it is only hard fate, and the grim logic of facts, which have at last compelled him to reject the brake which he has assured the world over and over again was as good a brake as could be had. Mr. Moon has not proved that he possesses any qualifications for selecting a brake. The case for Mr. Webb is not much better. He flatly opposed his own opinion to that of all the other railway officials in the kingdom, not one of whom would adopt his brake on a fast main line train, and he has manifested throughout a want of perception of what was needed in a brake, which does not encourage us to hope that he will make a better selection in future than he has done in the past.

The selection must be made within a very narrow circle. We do not mean to say a syllable in disparagement of several very ingenious devices which have been before the world for a greater or lesser period; but in truth there are but two systems from which a union of railway companies such as that of which we write can choose. These are the Westinghouse automatic, and the automatic vacuum brakes. It would be affectation on our part to pretend at this moment that it would be unfair to express an opinion of our own on the merits of the two systems. At such a time it is the duty of those who can influence public opinion to say what they think; and we have no hesitation in asserting that any great union of railway companies ought to adopt the automatic pressure brake. Let it be clearly understood that we not only willingly admit but gladly believe that there are excellent automatic vacuum brakes in the market. Those of Mr. Sanders, Mr. Aspinwall and Mr. Eames are all ingenious and all efficient, but they are not as efficient as the Westinghouse brake, and they have not received that cosmopolitan approval which has been bestowed on the Westinghouse brake. We have only to look to the records of public trials to see that as a train stopper the Westinghouse brake has never been beaten; and there is no other brake in the world employed to anything like the same extent, or with which anything like the same experience has been had. We have no desire to give figures here. They are very dry reading at the best of times, and we doubt that we should quite convey to our reader's mind what we wish him mentally to absorb, by a statement of the number of miles of line in this country and abroad worked with Westinghouse brakes. It will be more to the purpose if we explain that railway company after railway company has adopted the system, after the most careful deliberation, and that at this moment the Westinghouse Brake Company is making and fitting up probably ten brakes for every one made on any other system. So far as the Board of Trade and other reports go, the favor enjoyed by the system is justified by facts.

Dealing still with rumor, we hear that the London and Northwestern Company is likely to adopt a modification of the automatic vacuum brake. If this be done a mistake will be committed. In saying this we do not mean to say that the brake in question is not good and efficient. But even if we admitted, which we do not, that it was as good as the Westinghouse brake; it would still be the duty of the officials of great railway companies to select of the two that brake concerning which most was known, and about which the largest experience had been obtained. Two men, candidates for a given post, may be equally clever, equally well educated, and apparently equally competent to perform the duties required. But a prudent employer in

making his selection would choose the man who had been longest employed, and whose operations had extended over the largest area. This is the way of the world, and it ought to be the way with brakes as with men. It appears to us that the Westinghouse brake possesses this great advantage over all other brakes in the market, that concerning it everything which can be learned is known; whereas a great deal of information has yet to be acquired concerning all the other continuous brakes before the public. The Westinghouse brake is no longer experimental. The only other system of which the same thing can be said is Smith's vacuum brake, and that does not comply with the demands of the Board of Trade; and has been finally condemned as insufficient for the purposes of any great railway company. Under the circumstances we cannot see that the railway company we have named can do wrong if it follows the example recently set in France by a powerful company, and adopts the Westinghouse system. But if it does not feel disposed to do this, then it would be advisable, we think, to consult the railway department of the Board of Trade, and obtain a definite expression of opinion from its officers. On the whole we believe that the balance of advantage would be in favor of the course we urged last week, namely, the appointment of a small committee, in which the directors of various companies should be represented, and which should include a couple of engineer officers from the Board of Trade. Before this committee evidence might be given by the advocates of the different systems, and reports, facts and figures might be studied. The functions of the committee would be limited of course to recommending the adoption of one system out of the two or three from which alone a selection can be made; and it would be more satisfactory to all concerned if a choice of such vast importance was made in this way than by three or four locomotive superintendents, who, whatever the course they adopt, will find that they have been placed in a disagreeable and invidious position, and involved in a responsibility from which they might well shrink with annoyance, if not alarm.

THE THOMAS-GILCHRIST PROCESS.

From "Iron."

"My opinion is, that the success of the basic process is assured as replacing the puddling furnace, *in toto* or in part, as a means of manufacturing soft metal." Such is the conclusion—substantially the same as that arrived at by Professor Tunner—of the eminent and sagacious French chemist and metallurgist, M. Pourcel, of Terrenoire, in an article written last autumn (and lately reproduced in our columns) under the influence of the discussions and exhibitions of dephosphorizing practice which formed the leading feature of the Dusseldorf meeting of the Iron and Steel Institute. This very remarkable expression of opinion is, however, qualified by the uncertainty expressed by M. Pourcel as to whether or no the new process will successfully rival the old acid Bessemer process in the manufacture of hard metal. We may note, however, that, despite the partial hesitation expressed by M. Pourcel, no less than five-and-twenty Bessemer converters on the Continent are now engaged in the manufacture of not only soft but hard steel by the Thomas-Gilchrist process. In face of these decisive opinions from such men as M. Pourcel, Von Tunner, Trasenster, and others, and the still more significant fact of such an extensive practical working, the position of English ironmakers—who have up till now been left far behind by their foreign rivals in the adoption of the basic process—is both anomalous and dangerous, and the sooner they endeavor to appreciate the exact value of the new departure in its economic bearings the better. It is somewhat remarkable that, up to the present time, no serious effort has been made to examine in detail the economic aspect of dephosphorization in

its bearing on English ironmaking, though we have had exhaustive treatises on its bearing on Austrian, French, German and Belgian metallurgy. This deficiency, it is proposed here to attempt to supply, so as to do something towards clearing away the cloud of prejudice and uncertainty which has gathered about the subject, by dealing solely with facts and figures.

The points which seem on all hands to be substantially admitted are:

(1) That, in the manufacture of soft steel (or ingot iron), a metal may be made as pure, or purer, by the new Bessemer or Siemens process from phosphoric pig, as, by the old processes, is made from hematite pig.

(2) That there are no technical difficulties in carrying out the process on a large scale.

The points that were still, to a certain extent, under discussion at the time of the Dusseldorf meeting, but on which much light has since been thrown, were:

(3) Whether hard steel could be manufactured by the new process without special cost and difficulty.

(4) The precise cost of converting phosphoric pig into steel, as compared with the cost of conversion of non-phosphoric pig. Since last September, Messrs. Bolckow, Vaughan & Co., Messrs. Schneider, the Angleur, Rhenish. Höerde, Bochum, and other companies, have, it is understood, proved to the satisfaction of nearly all the railway companies, both of the Continent and England, that rails manufactured by the lime process can be made quite as hard as by the old Bessemer process; so that the assertion that the new steel was only fit for replacing wrought iron has become untenable, and has been tacitly abandoned; and the manufacturers of basic steel are now as willing to accept specifications for four-tenths per cent. of carbon as for two-tenths. The best opinion among engineers continues, however, to incline more and more to the belief that safety and durability in rails are rather to be found in soft than in hard steel; and it is probable that the American formula, based on Dr. Dudley's latest researches, prescribing about three-tenths of carbon, and not more than four-hundredths per cent. of silicon, will be more and more widely adopted by engineers. In Germany the tendency to prefer soft to hard steel is even more marked than elsewhere; and the tests prescribed practically limit steelmakers to from two to three-tenths per cent. of carbon for rails, and a still smaller proportion for sleepers. The question whether steel with over five-tenths per cent. of carbon can be made as readily by the new as by the old process is still one on which, as M. Pourcel says: "We are not in a position to speak confidently." As, however, it is doubtful if five per cent. of the three million and odd tons of Bessemer steel made in 1880 contained anything like five-tenths of carbon, this consideration is not an important one. There is, however, one great advantage claimed, and seemingly with justice, for the new metal, which is certainly not possessed by ordinary Bessemer steel—that is, the far smaller proportion—or, rather, complete absence—of silicon, an element which, as stated by a well-known steelmaker at a recent meeting of the Iron and Steel Institute, often gives more trouble than phosphorus. We may take it that, if the new process may be relied on, as appears to be the case, to produce steel with any content of carbon between five hundredths and five-tenths per cent., that practically ninety-nine hundredths of the ground open to the steelmaker is covered. The question of the real position of the Thomas-Gilchrist process is, therefore, after all, narrowed down to a question of "What will it cost?" It has always been admitted, even by its friends, that, assuming the price of pig to be equal, the basic process at present costs more than the acid. The point now to be determined is, as M. Pourcel says, the necessary margin of cost between hematite and phosphoric pig to allow of the latter competing with the former as a raw material for steelmaking. Another, and not less important question, hangs, however, on this one of the cost of conversion by the lime process. The future of the iron trade depends in a large measure upon whether the manufacture of soft ingots by the basic process costs more or less than the manufacture of puddled bars by puddling from pig iron of equal value. The proper appreciation of the right answer to this question is a matter of the highest import-

ance to British industry; and it would seem that we have now all the elements to enable us to form an independent and reliable opinion; M. Pourcel's paper forming a convenient basis for the investigation. It would appear that what may be called the excess costs of the new process may be classed under four heads, viz., cost of lime, cost of lining, cost of waste and extra labor, and cost of extra plant required to prevent reduced make. From the data given in M. Pourcel's paper and elsewhere, it seems that about 3½ cwt. of lime are used for additions per ton of steel produced. Now, the average cost of burnt lime in Cleveland, Sheffield, Wales, Staffordshire, Northamptonshire, and Lincolnshire varies between 7s. and 12s.; the mean value being about 9s. 6d. per ton. Taking, however, 10s. per ton for the cost of lime, we find the lime additions per ton of steel will cost 1s. 9d. The slag produced, containing from 10 to 20 per cent. of phosphoric acid and about 60 per cent. of lime, is at present used as a flux in the blast furnace, but its obvious ultimate destination is to be used as a manure, as phosphate of lime is at present worth from 1s. to 3s. per unit. Whatever, however, may be the ultimate value of the slag, whether as a flux or a manure, it will be safest to, at present, treat it as nil. With regard to the cost of lining, it is best to examine the facts rather than M. Pourcel's curious deductions. In one paragraph M. Pourcel says:

"At Ruhrort the vessel stops after forty blows, for repairs, whether general or partial I am unable to say." He then assumes that the whole lining is renewed (having previously stated that he did not ascertain if this were the case or not), and states that M. Transenter's figures on the cost of lining are inadmissible, as they do not agree with the assumption (made by M. Pourcel; as he himself states, in perfect ignorance) that the whole lining is repaired. Now, if M. Pourcel had taken the trouble to ask the courteous managers of the Rhenish Works he would have been told, as were others of their visitors, that the total consumption of both linings and bottoms amounted to 50 kilos, or, say 1 cwt. per ton of steel produced. Now, it appears that the price now charged in England (by the Raisby Hill Lime Company) for lime bricks is about 45s. a ton, adding 20s. a ton as a liberal allowance for labor and carriage, we have 3s. 3d. for the actual total cost of basic linings and bottoms. This is, however, probably considerably in excess of the actual cost to such firms as Bolckow, Vaughan & Co., who manufacture their own basic material. Now, the ordinary cost for linings and bottoms in the old Bessemer process varies from 1s. to 1s. 9d. a ton, which leaves the present excess cost for the new process at about 2s. per ton.

It seems admitted on all sides that an old Bessemer plant worked on phosphoric pig will not, on account of the smaller durability of the lining, be capable of the same output as when working on non-phosphoric pig. Arrangements have, therefore, to be made for duplicating or removing the vessels or vessel shells. Fortunately, however, this is the least expensive part of the plant, the blowing and hydraulic machinery having the same productive capacity on the one system as the other. The duplication or removal of the vessels, either of which devices will render the output with the basic system at least as great as with the acid, has been found to add from £3,000 to £6,000 to the cost of a Bessemer plant. Now, 10 per cent. for interest and sinking fund, on the larger of these sums, equals £600 a year, or, on a make of 2,000 tons a week, rather less than 1½d. per ton. If the make of modern American plant—say 3,000 tons a week—were attained, this item would sink to 1d. per ton. We may, however, take it, for simplicity, as 2d. per ton of steel made.

On the question of waste, we are, as M. Pourcel remarks, still without any precise figures. Collating, however, the figures given by M. Pourcel and Messrs. Richards, Massenez, Cooper, Pink and others, we find that the waste on the new process varies between 11 and 18 per cent., the mean being 14½ per cent. It will, however, be perhaps safest to assume for the present a waste of 15½ per cent. for the basic process and 12½ per cent. for the acid, the latter being, perhaps, rather below the English and American average. Now, a waste of 12½

per cent. on pig worth 60s. a ton, the present minimum price of hematite, represents a cost of 7s. 6d., while a waste of $15\frac{1}{2}$ per cent. on pig worth 40s. (the present normal price of Cleveland pig) represents a cost of only 6s. 3d. In other words, on the item of loss, the net gain on working Cleveland pig at Middlesbrough over Cumberland hematite at Barrow, or Workington, is 1s. 3d. per ton of steel.

The exact cost of the extra labor required in the basic system cannot be very precisely ascertained; we may, however, arrive at the figures pretty closely. We have first to consider the cost of throwing, say, 4 cwt. of lime into the converter, secondly, of removing 4 cwt. extra of slag.

Now, the cost of moving 1 ton of material in ironworks, as, for instance, in loading or unloading, is usually reckoned at 2d. per ton. The cost of moving 8 cwt. of slag and lime may, therefore, be taken at approximately 1d. To this we may probably add 6d. a ton, for contingencies and extra labor on repairs.

Summarizing these figures, we obtain the following as the extra cost on producing a ton of steel by the Thomas-Gilchrist process:

	s.	d.
$3\frac{1}{2}$ cwt. of lime, at 10s. per ton,....	1	9
Extra cost of basic lining over siliceous lining..........................	2	0
Interest and sinking fund on extra plant required....................	0	2
Extra labor and incidental expenses..	0	7
Deduct smaller money value of $15\frac{1}{2}$ per cent. loss on pig at 40s. over $12\frac{1}{2}$ per cent. loss on pig at 60s....	1	3
Net extra basic cost.............	3	3

Now this conclusion differs very materially from that of M. Pourcel and other continental critics. The reasons for this difference appear to be the following:

It was early assumed, on *a priori* grounds, on the Continent, that direct blast furnace metal could not be worked by the lime process, and the calculations of cost have been largely based on this assumption, thus, Von Tunner debits it with 8 fr. a ton on this account. Now, so far from this being the case, nothing but direct metal is used either at Eston or Creusot, and this with the best results. It is also assumed by M. Pourcel and M. Trasenster that a special and expensive manganiferous pig must be used, but, here again, experience has falsified the predictions of very able metallurgists, and Mr. Richards informs us that ordinary Cleveland forge and white pig made from Cleveland stone alone has been used at Eston for the past six months with perfect success. Finally, the consumption and price of basic lining materials have both been placed at a far higher figure than later experience warrants. Thus, we learn that at all the Continental works now working the lime process the average life of the basic bottoms considerably exceeds the average duration of gannister bottoms in England, while the cost of basic lining material in England is little more than half the price stated by M. Pourcel to be paid in Germany.

We are thus irresistibly led to two conclusions. First, that wherever the cost of phosphoric pig, moderately low in silicon and sulphur, is more than 7s. or 8s. a ton less than the cost of hematite Bessemer pig, the basic process will be inevitably sooner or later adopted. Second, that steel ingots can at this moment be produced for less than puddled bars everywhere, since it is generally admitted that, using pig iron of equal value, the cost of producing puddled bars is at least 6s. a ton greater than that of producing steel ingots.

THE Russian Finance Minister has just concluded an inquiry through the Department of Manufacture and Commerce into the state of the Russian commercial fleet. On the 1st of January this fleet stood as follows: The ports of the White Sea had 11 steamers of 916 lastels tonnage, 575 sailing vessels of 14,512 lastels; Baltic ports, 63 steamers of 9,539 lastels, and 578 sailing vessels of 43,771 lastels; Black Sea and Sea of Azof, 171 steamers of 29,564 lastels, and 1,964 sailing vessels of 76,091 lastels; Caspian, 36 steamers of 5491 lastels, and 1,004 sailing vessels of 49,656 lastels; Pacific Ocean, 15 steamers of 10,000 lastels. In all 296 steamers of 55,510 lastels, and 4,121 sailing vessels of 184,130 lastels. Of the total number—4,417—1,196 are employed in deep-sea navigation, and 3,221 in the coasting trade. Of the total number, 3,695 have been built in Russia and 722 abroad.

THE POLARISCOPE.

By J. P. BATTERSHALL, Ph. D.

Contributed to Van Nostrand's Engineering Magazine.

During the past quarter of a century the importance of scientific research and discovery, in their practical bearings on subjects intimately connected with the interests of manufacturers, has become more and more clearly demonstrated. Perhaps the most striking illustration of this fact is afforded by the instrument commonly known as the Polariscope (but more correctly termed the Saccharimeter), which is at present almost universally employed by sugar merchants, for the purpose of determining the actual value of their merchandise. This instrument has received somewhat frequent mention of late in the newspapers; an explanation of the salient principles involved in its construction may, therefore, be of interest to the general reader. In order to convey an intelligent idea of the physical laws which govern the practical working of the Polariscope, it will first be necessary to refer to the subject of the polarization of light. The transformation of ordinary into polarized light is best effected either by reflection from a glass plate at an angle of about 56°, or by what is known as double refraction. The former method can be illustrated by Fig. 1, which represents two tubes, B and C, arranged so as to allow the one to be turned round within the other. Two flat plates of glass, A and P, blackened at the backs, are attached obliquely to the end of each tube at an angle of 56°, as represented in the figure. The tube B, with its attached plate, A, can be turned round in the tube C without changing the inclination of the plate to a ray passing along the axis of the tube. If a candle be now placed at I, the light will be reflected from the plate P through the tube, and, owing to the particular angle of this plate, will undergo a certain transformation in its nature, or, in other words, become "polarized." So long as the plate A retains the position represented in the figure, the reflected ray would fall in the same plane as that in which the polarization of the ray took place, and an image of the candle would be seen by an observer stationed at O. But, suppose the tube B to be turned a quarter round; the plane of reflection is now at right angles to that of polarization, and the image will become invisible. When the tube B is turned half way round, the candle is seen as brightly as at first; at the third quadrant it disappears, until, on completing the revolution of the tube, it again becomes perfectly visible. It is evident that the ray reflected from the glass plate P has acquired properties different from those possessed by ordinary light, which would have been reflected by the plate A in whatever direction it might have been turned.

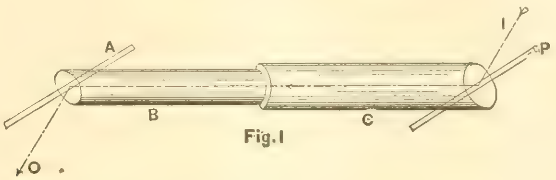


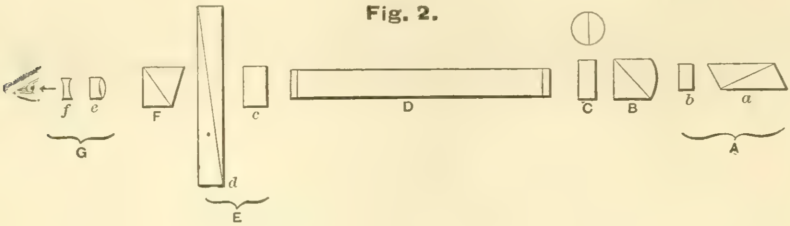
Fig. I

If a ray of common light be made to pass through certain crystals, such as calc spar, it undergoes double refraction, and the light transmitted becomes polarized. The arrangement known as Nichol's prism, which consists of two prisms of calc spar, cut at a certain angle and united together by means of Canada balsam, is a very convenient means of obtaining polarized light. If two Nichol's prisms are placed in a similar position, one behind the other, the

light polarized by the first (or polarizing) prism passes through the second (or analyzing) prism unchanged; but if the second prism be turned until it crosses the first at a right angle, perfect darkness ensues. While it would exceed the limits of the present article to enter fully upon the theoretical explanations which are commonly advanced concerning the cause and nature of this polarized, or transformed light, it may be well to state here that common light is assumed to be composed of two systems of beams which vibrate in planes at right angles to each other, whereas polarized light is regarded as consisting of beams vibrating in a single plane only. If, now, we imagine the second Nichol's prism to be made up of a series of fibers or lines, running only in one direction, these fibres would act like a grating and give free passage to a surface like a knife blade only when this is parallel to the bars, but would obstruct it if presented transversely. This somewhat crude illustration will, perhaps, serve to explain why the rays of light which have been polarized by the first Nichol's prism are allowed to pass through the second prism when the two are placed in a similar position, and why they are obstructed when the prisms are crossed at right angles, it being remembered that in a polarized ray the vibrations of the beams of light take place in a single plane.

Suppose we place between the two Nichol's prisms, while they are at right angles, a plate cut in a peculiar manner from a crystal of quartz—we will discover that rays of light now pass through the second prism, and that the field of vision has become illuminated with beautiful colors—red, yellow, green, blue, etc., according to the thickness of the quartz plate used. On *turning* the second Nichol's prism on its axis these colors will change and pass through the regular prismatic series, from red to violet, or the contrary, according to the direction of the rotation produced by the intervening plate. Quartz, therefore, possesses the remarkable property of rotating the plane of polarization of the colored rays of which light is composed; and it has been discovered that some plates of this mineral exert this power to the right, others to the left; that is, they possess a right or left-handed circular polarization. Numerous other substances, including many organic compounds, possess this property of causing a rotation—either to the right or left—of a plane of polarized light. For example, solutions of cane sugar and ordinary glucose cause a right-handed rotation, whilst uncrystalized sugar exerts a left-handed rotation. The extent of this power is directly proportional to the concentration of the solutions used, the length of the column through which the ray of polarized light passes being the same. It follows that on passing polarized light through tubes of the same length which are filled with solutions containing different quantities of impure cane sugar, an estimation of the amount of pure cane sugar contained in the tubes can be made by determining the degree of right-handed rotation produced; and it is upon this fact that the application of the polariscope in sugar analysis is based. The optical portions of the most improved form of the Polariscope—that known as the Ventzke-Scheibler—are represented by Fig. 2.

Fig. 2.



The light from a gas burner enters at the extremity of the instrument and first passes through the "regulator A," which consists of the double refracting Nichol's prism *a* and the quartz plate *b*, it being so arranged that it can be turned round its own plane, thus varying the tint of the light used, so as to best neutralize

that possessed by the sugar solution to be examined. The incident ray now penetrates the polarizing Nichol's prism B, and next meets a double quartz plate C (3.75 millimeters in thickness). This quartz plate, a front view of which is also shown in the figure, is divided in the field of vision, one-half consisting of quartz rotating to the right hand, the other half of the variety which rotates to the left hand. It is made of the thickness referred to, owing to the fact that it then imparts a very sensitive tint (purple) to polarized light, and one that passes very suddenly into red or blue when the rotation of the ray is changed. Since the plate C is composed of halves which exert opposite rotary powers, these will assume different colors upon altering the rotation of the ray. After leaving the scope. The Nichol's prism and quartz plate which constitute the "regulator" are situated at A and B, and can be rotated by means of a pinion connecting with the button L. The polarizing Nichol's prism is placed at C, and the double quartz plate at D. The receptacle *h* contains the tube P filled with sugar solution, and is provided with the hinged cover *h*', which serves to keep out the external light while an observation is being taken. The right-handed quartz plate and the wedge-shaped quartz prisms (corresponding to *c* and *d*, Fig. 2) are situated at G and at E and F, and the analyzing Nichol's prism is placed at H. When the wedge-shaped prisms have an equal thickness coinciding with that of the quartz plate *c* (Fig. 2) the left-handed rotary power of the former is

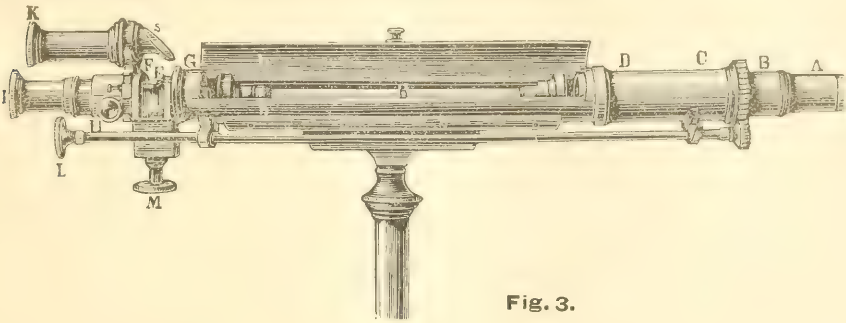


Fig. 3.

double quartz plate the light, which, owing to its passage through the Nichol's prism B is now polarized, enters the tube D containing the solution of cane sugar under examination; this causes it to undergo a right-handed rotation. It next meets the "compensator" E, consisting of a quartz plate *c*, which has a right-handed rotary power, and the two quartz prisms *d*, both of which are cut in a wedge shape and exert a left-handed rotation. They are so arranged that one is movable and can be made to slide along the other, which is fixed, thus causing an increase or decrease in their combined thickness and rotary effect. The ray of light then passes through the analyzing Nichol's prism F, and is finally examined by means of the telescope C, with the objective *e* and ocular *f*. Fig. 3 gives a perspective view of the Ventzke-Scheibler polari- exactly neutralized by the right-handed rotary power of the latter, and the field of vision seen at I is uniform in color, the opposing rotary powers of the two halves of the double quartz plates C (Fig. 2) being also equalized. But if the tube, filled with a sugar solution, is placed in the instrument, the right-handed rotary power of this substance is added to that half of the double quartz plate which exerts the same rotary effect (the other half being diminished in a like degree), and the two divisions of the plate will now appear of different colors. In order to restore an equilibrium of color, the movable wedge-shaped quartz plate E is slid along its fellow F by means of the rachet M, until the right-handed rotary power of the sugar solution is compensated for by the increased thickness of the left-handed plate, when the sections of the plate C will again ap

pear uniform in color. For the purpose of measuring the extent to which the unfixed plate has been moved, a small ivory scale is attached to this plate, and passes along index scale connected with the fixed plate. The degrees marked on the scale, which are divided into tenths, are read by aid of a mirror *s* attached to a magnifying glass K. When the polariscope is in what may be termed a state of equilibrium—*i. e.* before the tube containing the sugar solution has been placed in it—the index of the fixed scale points to the zero of the movable scale.

In the practical use of the Ventzke-Scheibler saccharimeter, the method adopted is essentially as follows: 13.024 grammes of the raw sugar to be tested are carefully weighed out and introduced into a flask 50 cubic centimeters in capacity; water is added, and the flask shaken until all crystals are dissolved. The solution is next decolorized by means of sub-acetate of lead, its volume made up to 50 cubic centimeters, and a little bone-black having been added if necessary, a glass tube, corresponding to P (Fig. 3), which is exactly 200 millimeters in length, and is provided with suitable caps, is completely filled with the clear filtered liquid. This is then placed in the polariscope, and protected from external light by closing the cover shown at h'. On now observing the field of vision by means of the telescope, it will be seen that the halves into which it is divided exhibit different colors. The screw, M, is then turned to the right until this is no longer the case, and absolute uniformity of color is restored to the divisions of the double quartz plate C (Fig. 2). The extent to which the screw has been turned, which corresponds to the right-handed rotation caused by the sugar solution, is now ascertained on reading the scale by aid of the glass K. The instrument under con sideration is so constructed that, when solutions and tubes of the concentration and length referred to above are used, the reading on the scale gives directly the percentage of pure crystallizable cane sugar contained in the sample examined. For instance, if the index zero of the fixed scale points to 96.°5 on the movable scale, after uniformity of color has been obtained, the sample of sugar taken contains 96.5 per centum of pure cane sugar. The results given by the polariscope possess an accuracy rarely, if ever, attained by any other apparatus employed in the determination of practical commercial values. It may be added, in this connection, that so long as sugar is bought and sold by merchants, according to its actual saccharine strength as shown by the polariscope, the adoption of this instrument by the United States Treasury Department appears to be perfectly justifiable, so far as the question of the accuracy of its indications is concerned. It would seem that the Government simply desires to determine the true value of imported sugar by means of the most accurate method known; and this opinion is supported by the fact that the experts employed for the purpose of sugar testing are gentlemen selected by the Appraiser, Hon. James Q. Howard, solely on account of their scientific reputation and practical experience in this particular branch of work. Another strong justification for the adoption of the polariscope in the clasification of sugars is afforded by the fact that the artificial coloring of certain sugars known as "vacuum pan"—which is notoriously practiced with an intent to defraud the revenue—can be readily indicated by means of this instrument.

Attention is again being called to the formation of a permanent inoxydizable coating on iron articles. The Barff and Bower processes are very well known. A new process, devised by Mr. Ward, consists in the combined application of silicates and heat, this process being the basis of several subsequent processes for ornamenting the surface of the metal. The iron objects are coated with a silicate composition, which is applied either by means of a brush or by dipping the iron in a bath of the solution. The coating quickly dries upon the objects, which are then passed through a furnace heated according to the nature of the articles under treatment. The silicate composition is thus fused, and, it is said, absorbed into the pores of the metal, becoming homogeneous with it. Upon cooling the articles treated are found to be covered with a dull black coating.

THE ORIGIN OF THE ENGLISH MILE.

From "English Mechanic and World of Science."

An interesting paper (of which we propose to give the substance) on the subject of the English mile, was lately read to the Paris Academy, by M. Faye.

The mile of 1,609 meters, it is known, long passed as equivalent in length to a terrestrial arc of 1 minute—the degree containing 60 of these miles—in reality it contains 69.5, the error being about a sixth. This error, so long current, may have caused more than one disaster at sea. It delayed, for many years, the discovery of universal attraction. The first time the idea that the attraction of the earth retaining the moon in its orbit is the same thing as gravity, presented itself to Newton, he failed in the verification, because he then employed the mile in calculating the earth's radius. He thought he must renounce the idea, and he only returned to it, when he became acquainted much later with the measurement of a degree executed by Picard, in France.

Whence this evaluation so defective, so unfit for the purposes of navigation? The worst measures of a degree really made, like that of Posidonius, are far from presenting such errors. The English geographers must have made some mistake in taking their mile from ancient documents.

It cannot be supposed, indeed, that geographers took the first mile as a measure of the terrestrial minute. So long as navigation was limited to the Mediterranean and the western coasts of Europe, there was no occasion to study the value of this element; but when the Spaniards and Portuguese had opened up a wider range, sailors were obliged to inquire into it. The English navigator probably applied to the geographers, and the latter could not find a better course than to consult Ptolemy, the great and only authority in such matters.

Now, Ptolemy himself referred to Eratosthenes; he says he had verified his measures and found the same thing, viz., 500 stadia to a terrestrial degree. I was thus led to study Eratosthenes' measure. According to documents that are preserved, Eratosthenes appears to have measured the great meridian arc which separates the parallel of Syene and Alexandria, and he found 700 stadia to a degree. Eratosthenes was a Greek astronomer established in Alexandria 250 years, B. C. Called to Egypt and patronised by Philadelphus, he benefited by the liberality of a king, friendly to science and arts. He himself erected, at Alexandria, astronomical instruments that were very well conceived. He operated thus:

He observed at Alexandria, pretty certainly with the aid of a gnomon, the zenith distance of the sun at midday, on the day of the summer solstice, and found it 7° 12′. It is added that at Syene the bottom of certain pits was fully illuminated by the sun on that day, so that Eratosthenes concluded zero for the zenith distance of the sun. Probably, however, the learned Greek obverved at Syene also with a gnomon, an instrument widely distributed in Egypt.

The amplitude 7° 12′ concluded by Eratosthenes is correct; it has, moreover, the advantage of not having been affected by refraction.

One verification is afford by the *Connaissance des Temps*, where one finds

For the latitude of Alexandria.	31°12′
" " " Syene......	24° 5′
Difference..	7° 7′

instead of 7°12′; the discrepance is small.

There is a second and more delicate verification. The latitude of the point at Alexandria, where Eratosthenes observed, could not differ much from that just given. Adopting it, and 7°12′ for the zenith distance of the upper limb of the sun at the summer solstice, one finds $31°12'—(7°12'+16)=23°44'$ for the obliquity of the ecliptic. Syene gives $24°5'-16'=23°49'$. Is it possible that in the year—250 the obliquity of the ecliptic was from 23° 44′ to 23° 49′? The reply is, that from 1750 to—250 are 2,000 years. At the rate of 48″ diminution in a century, the obliquity would be

$23° 28' 18'' + 48'' \times 20 = 23° 44'$. Thus the observation of Eratosthenes at Alexandria is authentic and very precise. That at Syene presents a discrepance of only 5′.

There remains the geodesic operation. Egypt was the only country of antiquity which boasted a survey. The valley of the Nile was largely peopled at this time, up to the Syene. Doubtless the survey extended thither. Eratosthenes must have had every facility for obtaining the necessary documents. A people who knew so well how to direct its monuments must, by its immense surveying operations, have known not only the distances, but the orientation. Eratosthenes would take account of the difference of longitude, 2° 59′, existing between the two cities, without requiring to determine it directly. I regard, then, the distance of 5,000 stadia, in round numbers, as being quite as serious as the other part of his operation, and as applying to the arc of meridian comprised between the parallel of the two cities.

The number 694.4 stadia was finally concluded for a degree. The Greek astronomer gives in round numbers 700 stadia. What was this stadium?

To answer this question, I calculate the arc of meridian, from Alexandria to the parallel of Syene, with the actual elements of the terrestrial ellipsoid. It is 797,760m.; accepting 5,000 stadia, we find 159.55m. for the stadium. With 600ft. to the stadium, the foot adopted by Eratosthenes would be 0.266m. It was, then, the ancient Egyptian foot, which we now estimate at 0.27m., and, in fact, it was with this foot that the survey of Egypt seems to have been made. On this reckoning $5{,}000 \times 600 \times 0.27 = 810{,}000$m., the difference, 12,240m., is imputable in part to that of the points of departure, in part to the error we, perhaps, make as to the length of the Egyptian foot in raising it to 0.27m. Thus, the measurement executed in Egypt more than 21 centuries ago, by an able Greek astronomer, is as good as authentic. All the causes of uncertainty do not alter it 1-60th; and it is certainly not from this quarter that the error of 1-6th, which we are seeking to account for, comes.

No more does it come from the measurement of Ptolemy, for he performed the same operations, and obtained the same result. Only, he gives 500 stadia to a degree, instead of 700. This difference evidently arises from the fact that Ptolemy, who lived four hundred years after Eratosthenes, under another rule, did not employ the same foot. In fact, he employed the stadium of 600 Phileterian feet, and as this foot is nearly 0.36m., while the ancient Egyptian foot was only 0.27m., it was necessary to reduce the 700 stadia of his predecessor to $700 \times = \frac{27}{36} = 525$, or 500 in round numbers.

These appreciations are confirmed by the Arabian astronomers who measured in 827, an arc of 1° in the plains of Mesopotamia. They obtained 56 miles, and concluded that they had thus verified the number of Ptolemy. The Arabian mile was 2,100m.; the arc measured was found 117,600m., which answers to a stadium of 235m. This is pretty near the Phileterian stadium of 216m., allowing for the error of measurements, seven times more sensible on an axis so small, and the uncertainty of our present estimation of the Arabian mile in the time of the caliph Almamoun.

En résumé, the evaluation of Ptolemy is merely a sort of conversion of the excellent measure of Eratosthenes into units of another epoch, and different length. It must have lost, thus, a little of its first precision; but, as presented by Ptolemy, the English geographers had good reason to take it as base of an evaluation of the arc of one degree, and to offer it to nautical men of their country. Only, and here is the mistake, they believed that the great Greek astronomer of Alexandria used the Greek foot. This is one hundredth and a half more than the English foot. If the English geographers of the 16th century forced this evaluation but a little and carried it to 5 hundredths, they would have found 630 English feet to the stadium, which they believed to have 600 Greek feet, and these 630 feet, or these 210 yards, multiplied by 500, would have given them 105,000 yards for the degree, and exactly 1,760 yards for the mile.

The English mile, then, has probably been deduced from the measure of Ptolemy; its error of 1-6th is due simply to confounding the Greek foot with the Phileterian foot.

THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

Address of the President, JAMES B. FRANCIS, before the Annual Convention at Montreal.

You have assembled in convention for the first time outside the limits of the United States, and I congratulate you on the selection of this beautiful city, in which and its immediate neighborhood there are so many interesting engineering works, constructed with the skill and solidity characteristic of the British school of engineering. Nine of our members are Canadian engineers, which must be the excuse of the other members for invading foreign territory.

The Society was organized Nov. 3, 1852, and actively maintained up to March 2, 1855. Eleven only of the present members date from this period. October 2, 1867, the Society was reorganized on a wider basis, and from that time to the present, it has been constantly increasing in interest and usefulness.

The membership of the Society is now as follows;

Honorary members	11
Corresponding members	3
Members	491
Associates	21
Juniors	57
Fellows	53
Total	636

During the last year we have lost six members by death and five by resignation, and fifty-six new members have been elected and qualified.

The most interesting event to the Society since the last convention, has been the purchase of a house in the City of New York, as a permanent home, at a cost of $30,000. This has been accomplished, so far, without taxing the resources of the Society, the required payments having been met by subscription. The sum of $11,900 had been subscribed to the building fund up to the 25th ultimo, by seventy members, and twenty-nine friends of the Society who are not members. The subscription is still open, and it is expected that large additions will be made to it by members and their friends, to enable the Society to make the remaining payments without embarrassment.

Meetings of the Society are held twice in each month, during ten months in the year, for the reading and discussion of papers and other purposes; the new house affords much better accommodations for these purposes than we have ever had before, and also for the library, which now contains 8,850 books and pamphlets, and is constantly increasing. A catalogue of the library is being prepared. Part I., embracing railroads and the transactions of scientific societies, has been printed and furnished to members.

WATER POWER.

Water power in many of the States is abundant, and contributes largely to their prosperity. Its proper development calls for the services of the civil engineer, and as it is the branch of the profession with which I am most familiar, I propose to offer a few remarks on the subject.

The earliest applications were to grist and saw mills; carding and fulling mills soon followed; these were essential to the comfort of the early settlers, who relied on home industries for shelter, food and clothing, but with the progress of the country came other requirements.

The earliest application of water power to general manufacturing purposes, appears to have been at Paterson, New Jersey, where "The Society for establishing Useful Manufactures" was formed in the year 1791. The Passaic river at this point furnishes, when at a minimum, about eleven hundred horse power continuously, night and day.

The water power at Lowell, Massachusetts, was begun to be improved for general manufacturing purposes in 1822. The Merrimack river, at this point, has a fall of thirty-five feet, and furnishes, at a minimum, about ten thousand horse power, during the usual working hours.

At Cohoes, in the State of New York, the Mohawk river has a fall of about one hundred and five feet, which was brought into use systematically very soon after that at Lowell, and could

furnish about fourteen thousand horse power, during the usual working hours; but the works are so arranged that part of the power is not available at present.

At Manchester, New Hampshire, the present works were commenced in 1835. The Merrimack river, at this point, has a fall of about fifty-two feet, and furnishes, at a minimum, about ten thousand horse power, during the usual working hours.

At Lawrence, Massachusetts, the Essex Company built a dam across the Merrimack river, commencing in 1845, and making a fall of about twenty-eight feet, and a minimum power, during the usual working hours, of about ten thousand horse power.

At Holyoke, Massachusetts, the Hadley Falls Company commenced their works about 1845, for developing the power of the Connecticut river at that point, where there is a fall of about fifty feet, and at a minimum, about seventeen thousand horse power, during the usual working hours.

At Lewiston, Maine, the fall in the Androscoggin river is about fifty feet; its systematic development was commenced about 1845, and with the improvement of the large natural reservoirs at the head waters of the river, now in progress, it is expected that a minimum power, during the usual working hours, of about eleven thousand horse power will be obtained.

At Birmingham, Connecticut, the Ousatonic Water Company have developed the water power of the Housatonic River, by a dam giving twenty-two feet fall, furnishing, at a minimum, about one thousand horse power, during the usual working hours.

The Dundee Water and Land Company, about 1858, developed the power of the Passaic river, at Passaic, New Jersey, where there is a fall of about twenty-two feet, giving a minimum power, during the usual working hours, of about nine hundred horse power.

The Turner's Falls Co. in 1866, commenced the development of the power of the Connecticut River at Turner's Falls, Massachusetts, by building a dam on the Middle Fall, which is about thirty-five feet, and furnishes a minimum power, during the usual working hours, of about ten thousand horse power.

I have named the above water powers as being developed in a systematic manner from their inception, and of which I have been able to obtain some data. In the usual process of developing a large water power a company is formed, who acquire the title to the property, embracing the land necessary for the site of the town to accommodate the population which is sure to gather around an improved water power. The dam and canals or races are constructed, and mill sites with accompanying rights to the use of the water are granted, usually by perpetual leases subject to annual rents. This method of developing water power is distinctly an American idea, and the only instance where it has been attempted abroad, that I know of, is at Bellegarde, in France, where there is a fall in the Rhone of about thirty-three feet. Within the last few years, works have been constructed for its development, furnishing a large amount of power, but from the great outlay incurred in acquiring the titles to the property, and other difficulties, it has not been a financial success.

The water powers I have named are but a small fraction of the whole amount existing in the United States and the adjoining Dominion of Canada. There is Niagara with its two or three millions of horse power; the St. Lawrence, with its succession of falls from Lake Ontario to Montreal; the Falls of St. Anthony, at Minneapolis, and many other falls, with large volumes of water, on the upper Mississippi and its branches. It would be a long story to name even the large water powers, and the smaller ones are almost innumerable. In the State of Maine a survey of the water power has recently been made, the result, as stated in the official report, being "between one and two millions of horse powers," part of which will probably not be available. There is an elevated region in the northern part of the South Atlantic States, exceeding in area one hundred thousand square miles, in which there is a vast amount of water power, and being near the cotton fields, with a fine climate, free from malaria, its only needs are railways, capital and population, to become a great manufacturing section.

The design and construction of the works for developing a large water

power, together with the necessary arrangements for utilizing it and providing for its subdivision among the parties entitled to it, according to their respective rights, afford an extensive field for civil engineers; and in view of the vast amount of it, yet undeveloped, but which with the increase of population and the constantly increasing demand for mechanical power, as a substitute for hand labor, must come into use, the field must continue to enlarge for a long time to come.

There are many cases in which the power of a waterfall can be made available by means of compressed air, more conveniently than by the ordinary motors. The fall may be too small to be utilized by the ordinary motors; the site where the power is wanted may be too distant from the waterfall, or it may be desired to distribute the power in small amounts at distant points.

*A method of compressing air by means of a fall of water has been devised by Mr. Joseph P. Frizell, C. E., of St. Paul, Minnesota, which from the extreme simplicity of the apparatus promises to find useful applications. The principle on which it operates is, by carrying the air in small bubbles in a current of water down a vertical shaft, to the depth giving the desired compression, then through a horizontal passage in which the bubbles rise into a reservoir near the top of this passage, the water passing on and rising in another vertical or inclined passage, at the top of which it is discharged—of course, at a lower level than it entered the first shaft.

The formation at waterfalls is usually rock, which would enable the passages and the reservoir for collecting the compressed air, to be formed by simple excavations, with no other apparatus than that required to charge the descending column of water with the bubbles of air, which can be done by throwing the water into violent commotion at its entrance, and a pipe and valve for the delivery of the air from the reservoir.

The transfer of power by electricity is one of the problems now engaging the attention of electricians, and it is now done in Europe in a small way. Sir William Thompson stated in evidence before an English Parliamentary committee, two years ago, that he looked "forward to the Falls of Niagara being extensively used for the production of light and mechanical power over a large area of North America," and that a copper wire half an inch in diameter would transmit twenty-one thousand horse power from Niagara to Montreal, Boston, New York or Philadelphia. His statements appear to have been based on theoretical considerations, but there is no longer any doubt as to the possibility of transferring power in this manner; its practicability for industrial purposes must be determined by trial. Dr. Paget Higgs, a distinguished English electrician, is now experimenting on it in the city of New York.

Great improvements in reaction water wheels have been made in the United States within the last forty years. In the year 1844 the late Uriah Atherton Boyden, a civil engineer of Massachusetts, commenced the design and construction of Fourneyron turbines, in which he introduced various improvements and a general perfection of form and workmanship, which enabled a larger percentage of the theoretical power of the water to be utilized than had been previously attained. The great results obtained by Boyden with water wheels made in his perfect manner, and in some instances almost regardless of cost, undoubtedly stimulated others to attempt to approximate to these results at less cost, and there are now many forms of wheel of low cost, giving fully double the power, with the same consumption of water, that was obtained from most of the older forms of wheels of the same class.

ANCHOR ICE.

A frequent inconvenience in the use of water power in cold climates is that peculiar form of ice called anchor, or ground ice. It adheres to stones, gravel, wood and other substances forming the beds of streams, the channels of conduits and orifices through which water is drawn; sometimes raising the level of water courses many feet by its accumulation on the bed, and entirely closing small orifices through which water is drawn for industrial purposes. I have been for many years in a position to observe its effects, and the conditions under which it is formed.

* Journal of the Franklin Institute for Sept. 1877.

The essential conditions are, that the temperature of the water is at its freezing point, and that of the air below that point; the surface of the water must be exposed to the air, and there must be a current in the water.

The ice is formed in small needles on the surface, which would remain there and form a sheet if the surface was not too much agitated, except for a current or movement in the body of water sufficient to maintain it in a constant state of intermixture. Even when flowing in a regular channel there is a continued interchange of position of the different parts of a stream; the retardation of the bed causes variations in the velocity which produces whirls and eddies, and a general instability in the movement of the water in different parts of the section. The result being that the water at the bottom soon finds its way to the surface, and the reverse. I found by experiments on straight canals in earth and masonry, that colored water discharged at the bottom reached the surface at distances varying from ten to thirty times the depth.* In natural water courses, in which the beds are always more or less irregular, the disturbance would be much greater. The result is that the water at the surface of a running stream does not remain there, and when it leaves the surface it carries with it the needles of ice, the specific gravity of which differs but little from that of the water, which, combined with their small size, allows them to be carried by the currents of water in any direction. The converse effect takes place in muddy streams. The mud is apparently held in suspension, but is only prevented from subsiding by the constant intermixture of the different parts of the stream; when the current ceases the mud sinks to the bottom, the earthy particles composing it, being heavier than water, would sink in still water in times inversely proportional to their size and specific gravity. This, I think, is a satisfactory explanation of the manner in which the ice formed at the surface finds its way to the bottom; its adherence to the bottom, I think, is explained by the phenomenon of *re-gelation*, first observed by Faraday; he found that when the wetted surfaces of two pieces of ice were pressed together they froze together, and that this took place under water even when above the freezing point. Professor James D. Forbes found that the same thing occurred by mere contact without pressure, and that ice would become attached to other substances in a similar manner. Re-gelation was observed by these philosophers in carefully arranged experiments with prepared surfaces, fitting together accurately, and kept in contact sufficiently long to allow the freezing together to take place. In nature these favorable conditions would seldom occur in the masses of ice commonly observed, but we must admit, on the evidence of the recorded experiments, that, under particular circumstances, pieces of ice will freeze together, or adhere to other substances, in situations where there can be no abstraction of heat.

When a piece of ice of considerable size comes in contact under water with ice or other substance, it would usually touch in an area very small in proportion to its mass, and other forces acting upon it, and tending to move it, would usually exceed the freezing force, and re-gelation would not take place. In the minute needles formed at the surface of the water the tendency to adhere would be much the same as in larger masses touching at points only, while the external forces acting upon them would be extremely small in proportion, and re-gelation would often occur, and of the immense number of the needles of ice formed at the surface, enough would adhere to produce the effect which we observe and call anchor ice. The adherence of the ice to the bed of the stream or other objects is always downstream from the place where they are formed; in large streams it is frequently many miles below; a large part of them do not become fixed, but as they come in contact with each other, re-gelate and form spongy masses, often of considerable size, which drift along with the current, and are often troublesome impediments to the use of water power.

Water powers supplied directly from ponds or rivers or canals frozen over for a long distance, immediately above the places from which the water is drawn, are not usually troubled with anchor ice, which, as I have stated, requires open water, upstream, for its formation.

* Paper CLX. in the Transactions of the Society, 1878. Vol. VII., pages 109, 168.

THE CORROSION OF IRON AND MILD STEEL.

From "The Engineer."

The minds of those interested in the extended use of mild steel for constructive purposes have lately been somewhat troubled. Mr. Philips, secretary to the late Admiralty Boiler Committee, read a paper a few weeks since before the Institution of Civil Engineers, setting forth the results of certain experiments made by that committee, together with certain others since made by himself. The conclusions deducible from these experiments were that mild steel under almost all conditions to which it is likely in practice to be exposed, corrodes much faster than wrought iron. If this be really the case it naturally follows that mild steel is a much less trustworthy material than it was supposed to be; and the reduction of weight of scantlings now allowed by Lloyd's surveyors, in consideration of superior tensile strength, ought to be in future prohibited, while the reduction in thickness in steel plates for marine boilers, as compared with iron, must also be discontinued. For it is not so much the strength of a structure when brand new that needs consideration, as its strength after a few years of active or passive service. If corrosion should be proved to be likely to do its deadly work upon steel considerably more rapidly and completely than upon iron, how can original reductions of thickness be any longer safely permitted when the more corrodible material is used? It is true that some rather severe criticisms were passed on Mr. Philips' paper during its discussion, but inasmuch as the Institution of Civil Engineers' meetings are not open to the public, nor attended otherwise than occasionally by members of the iron and steel trades, the unfavorable effect of the paper as regards mild steel might be considered still to remain in full force. In this position of affairs Mr. Parker's paper upon the same subject was placed first on the list at the recent meeting, in London, of the Iron and Steel Institute, and was generally pronounced to be extremely opportune. There is scarcely any one whose evidence on such a matter is entitled to more respect, whether on account of the writer's great practical experience, his thorough technical knowledge, his independent position, or his fearless candor, as testified by his recent paper on the "Livadia's" boilers. Mr. Parker was therefore expected to give valuable and trustworthy evidence, and so he did. Let us now consider what he said.

He first reviewed the experiments made by the Admiralty Boiler Committee, admitting that on the surface they appeared decidedly unfavorable to steel. He considered, however, that the deductions made from them were open to question, because in making the tests due care had not been taken to prevent galvanic action. He did not refer to the tests which Mr. Philips had subsequently made privately and on his own responsibility. Why this omission was made has yet to be explained. He next reviewed the experiments made more than forty years ago by Mr. Robert Mallet, and though he recognised some value in them, he considered that they also, on account of their want of completeness, are unavailing in settling the present question. He then carefully described his own experiments, made by exposing six bright and six black discs to six varieties of corroding conditions, obtained from each of two makers of common iron, four of high-class iron and four of mild steel plates. The discs were in all cases $4\frac{1}{2}$ in. diameter by $\frac{1}{4}$ in. thick. By means of glass insulators, and by carefully excluding other metals from the test groups, he endeavored to avoid galvanic action. He first gave the results obtained from the six groups of bright specimens, and afterwards from those which had been exposed to the black or unscaled condition, In the case of the bright specimens the loss by corrosion is given in pounds per square foot per annum. For the sake of simplicity we have further condensed the results to one average for cold and one for hot corrosion. The former includes exposing to the action of cold sea water, bilge water and the London atmosphere; the latter includes three experiments in the water spaces of sea-going boilers under slightly

different circumstances. The mean result in pounds per square foot per annum is as follows: Cold—Common iron, .267; best Yorkshire iron, .294; mild steel, .318. Hot—Common iron, .261: best Yorkshire iron, .298; mild steel, .376. In other words, the excess of liability to corrode over and above common iron plates is as follows: Cold—Best Yorksire, 10 per cent.; mild steel, 19 per cent. Hot—Best Yorkshire, 14 per cent., mild steel, 44 per cent.

The common iron comprised specimens of Cleveland and of Glasgow plates; the best Yorkshire of Leeds, Bowling, Farnley and Lowmoor; and the mild steel of Landore, Sheffield, Bolton and the Steel Company of Scotland's make. Leaving these startling results of the experiments with the bright discs for a moment, let us proceed to the consideration of those with the black discs. Here Mr. Parker does not give us the loss in pounds per square foot per annum, but having in his mind the fact that a plate perforated by pitting is as much spoilt as one rusted away equally over its surface, he confines himself to determining the average depth of corrosion locally, where accidentally denuded of scale, of black plates compared with the same generally of bright plates. He finds a great increase of irregularity resulting from carelessness in leaving the scale on. Thus, with the bright specimens, the ratio 80: 100 about expresses the maximum variation in the loss between any two specimens similarly tested, whether common or best Yorkshire iron, or mild steel. But with the black specimens, whilst 40: 100 expresses the variation for common iron, 30: 100 expresses that for best Yorkshire iron, and 20: 100 for mild steel. The fickleness of unscaled mild steel as to corrosion is apparently much greater than that of best Yorkshire iron, and double that of common iron. The general conclusion drawn by Mr. Parker from the experiments with the black specimens is, that leaving the scale on induces pitting, which is tantamount to more rapid destruction of the plates. Although scale may be, and no doubt is, a protection to the part it covers, it evidently contributes to the more rapid destruction of the neighboring parts; and, therefore, unless it be complete and enduring, as it may some day be made by the "Bower Barff" process, it is worse than useless. Mr. Parker advocates—and in this we fully agree with him—that in the meantime all scale should carefully be removed, leaving the bare metallic plate to ordinary oxidizing influences, in case of the removal of paint, or of such other covering as may be artificially given to it when the structure is new. Dismissing for this reason further consideration of unscaled plates, we have only to deal with those which have been scaled, and which are, therefore, correctly represented by the bright specimens. Indeed, as soon as the first film of rust pervades a bright plate, it is in exactly the same condition as a new plate from which the scale had been carefully removed. The question we have placed before us is, how is mild steel likely to stand corrosion in ships and in boilers, as compared with the iron of which these structures have hitherto been mostly made? Here, we regret to say, we find ourselves somewhat at variance from Mr. Parker. We accept, or rather we do not dispute his facts; but his conclusion seems to us unwarranted, and to some extent misleading. Perhaps we ought rather to say that the general impression conveyed by his own summing up of his paper is not, in our opinion, justified by his experiments. It is almost impossible at one sitting to grasp the full bearings of a technical paper, such as this, containing a number of statistical figures; and an audience naturally looks for guidance to the writer as to the conclusions they may properly draw. It is these conclusions which we, after a careful re-perusal, are disposed to find fault with. The following are extracts from Mr. Parker's paper, containing the conclusions referred to: "Although the average loss of steel is a little greater than of iron, the difference is so slight that for practical purposes it is safe to assume that bright steel, exposed to sea or bilge water, corrodes no faster than bright iron, especially than the better qualities of iron." "When exposed to the atmosphere, although there is no great difference between the common and the better sorts of iron, the steel appears to have lost considerably more than either Lowmoor or any other iron, and the same is the case with those discs exposed to the action of boiling water with or without zinc. Again, in another place: "So that

although the present experiments confirm the prevailing impression that bright mild steel does corrode faster than iron, when we get from cold sea water to the condition of a marine boiler the difference is not so great as to establish the matter beyond question." And further on: "It would perhaps not be far wrong, speaking generally, to say that the different pieces of iron differed as much among themselves as they did from steel; and certainly the effect produced on my mind after carefully weighing the results of the experiments has not been to raise any apprehension that steel boilers or steel ships are likely in the future to corrode to any serious extent more rapidly than iron." As to the practical working of the 1,100 steel boilers now in use: "Greater irregularity in the corrosion of the steel is reported, due to the unequal action of the scale; and, finally: "Neither from the series of experiments which I have described, nor from our daily experience up to the present time, is there any reason to believe that the question of corrosion is likely to form a bar to the extended use of steel for marine boiler-making purposes."

Now, when we consider that no ship afloat has been built of "Lowmoor" or any other prime brands of "best Yorkshire iron," or is any ever likely to be on account of the cost, there is no use introducing into the discussion the liability of such brands to corrosion as compared with steel in ship construction. Having successfully driven iron nearly out of the market for rails, steel makers are now naturally endeavoring to do the same as regards ship-building material. But it is the so-called common irons of Cleveland and Glasgow that have to be superseded, if any, and not those of Lowmoor or the Leeds district. In ships the corroding elements to be contended with are three, every part of the hull being liable to be acted on by one or other of these. They are cold sea water, bilge water and the atmosphere. The practical aim of the manufacture must therefore be, to make iron or steel which will stand any one of these destructive agencies—and no one can say to which one a particular plate will be most subjected. We therefore have amalgamated Mr. Parker's first three columns of results into one general result for "cold corroding," which nearly corresponds with ship-plate corrosion. This we have shown drives us to the startling conclusion that mild steel corrodes 19 per cent. faster than the iron ship plates at present in use. In other words, by the time a clean, unpainted Cleveland ship plate $\frac{5}{8}$ in. thick has corroded away, a $\frac{3}{4}$ in. mild steel plate would also be completely oxidized; and yet, the steel ships now under construction and afloat are not 20 per cent. thicker—as it would appear they ought to be—but 20 per cent. thinner than they would have been of iron.

As to boilers, the fact brought out by Mr. Parker that mild steel in boiler water spaces corrodes 44 per cent., and best Yorkshire iron 14 per cent. quicker than common iron, is startling in the extreme. Indeed, had Mr. Philips been present at the discussion—and it is a matter of regret that he was not—he would have been justified in making some rather pertinent and forcible observations. He might have said very properly: "It is contended that the Boiler Committee's experiments are valueless, and by inference that my whole paper, which included other confirmatory experiments, should be discredited; and yet this new set of experiments, in the making of which all previous faults have been avoided, has produced very similar results. I claim that the position I took has been strengthened, and not weakened." It must not be supposed that common iron is out of court in consideration of this part of the question. Common iron, as here understood, is the iron of the Cleveland and Glasgow districts. Large quantities of boiler plates are made in both these districts for marine and other purposes; and these are more carefully made than ship plates, yet they are mainly from the native pig irons; and as far as resistance to corrosion goes, there is no doubt they have all the good qualities of the lower brands. It is probable that the weight of iron from the whole best Yorkshire district worked up annually into marine boilers is quite insignificant compared to what at present is being supplied by Glasgow and the North of England. Indeed, mild steel has for long been so much cheaper in comparison that the question for consideration has been: "Shall it be Cleveland or Scotch iron boiler plate, or shall it be mild steel?"

And not. "Shall it be mild steel or best Yorkshire iron?" The very high initial cost and the heavy extras rigidly enforced, amounting in many cases to £50 to £60 per ton, have precluded the use of Yorkshire iron except, as it were, as a luxury. Much more might be said, if space permitted, about the physical properties of iron and steel. Professor Kennedy's paper, recently read before the Institution of Mechanical Engineers, and the discussion thereon, disclosed some remarkable facts, hitherto unknown or unappreciated. Among these we may mention: (1) That permanent set commences with mild steel—which alone is admissible for ships or boilers—at about 8 tons per square inch, as compared with 11 or 12 tons with North country iron; (2) that at about 18 tons per square inch a distinctive "breaking down" or disintegration takes place, which has no analogy in iron short of its final breaking strain of, say, 21 tons per square inch; and (3) that for thicknesses above ¾ in. or ⅞ in. mild steel is no stronger, and on account of the impossibility of doing sufficient work upon it, less trustworthy than iron But our present object has been to discuss Mr. Parker's valuable paper upon corrosion, and therefore we content ourselves with simply alluding to the physical peculiarities of steel just named. In, conclusion, we would ask shipowners shipbuilders, ship insurers and underwriters' surveyors to pause for a moment and ponder deeply, whether, metaphorically speaking, it is not possible there may be "rocks ahead" which will, in a not very distant future, play havoc with structures made of extra thin plates of extra corrodible material.

On the Work of a Man for Short Periods.—By Dr. Hartig.—At the fire brigade congress at Dresden in June, 1880, dynamometrical observations were made of the power required to work the different hand fire-engines exhibited. Amongst other results these experiments give an insight into the amount of work which can be performed by men working for very short periods at a lever.

The engines were placed in the open air, under a hot sun; they were worked by infantrymen, and each squad worked for two minutes only at a time. The following are selected from the table of seventeen experiments given in the paper:

Number of experiment		i	viii.	ix.	xi.	xvii.	mean of 17.
Mean height of lever above ground	inches	40.25	38.7	38.54	49.31	38.38	..
Length of lever	"	49.2	46.7	43.5	70.5	58.7	..
Stroke	"	38.8	35.0	35.9	45.5	37.4	..
Number of double strokes per minute		48	55	49	55	60	.
Mean velocity of handle	feet per sec.	5.17	5.33	4.9	6.95	6.23	5.78
Horse power exerted per man		0.324	0.227	0.403	0.306	0.395	0.297

Morin and Weisbach give 5.5 meter-kilogrammes per second = 2,387 foot-lbs. per minute as the work that a man can do for eight hours together; the above mean work is greater than this in the ratio $\frac{0.297 \times 33000}{2387} = 4.1$ nearly.

—*Der Civilingenieur.*

Different Varieties of Steel.—The following correct definitions of the different varieties of steel by William Metcalf, of the Crescent Steel Works, Pittsburgh, Pa., are published in a circular by the Dexter Spring Company, of Hulton, Pa.

Originally the word steel was applied only to iron which contained such quantities of carbon as would cause hardening when the red-hot iron was cooled suddenly.

This definition still applies, but, in addition, the term cast steel applies to all of the products of the crucible, the Bessemer converter, and the open-hearh furnace, whether such products are too low in carbon to harden or not. The steels that are not cast steel are known in the market as blister steel, German steel, shear steel, and double shear steel.

Blister steel is made by heating bars of wrought iron, bedded in charcoal, in hermetically sealed chambers. The carbon of the charcoal penetrates the hot

iron, converting it into a crystalline mass of crude steel; large blisters rise on the surfaces of the bars, giving the name blister steel to this product.

German steel is blister steel rolled down into bars. It is used mainly for tires and common springs, but is being rapidly superseded by the cheaper grades of cast steel.

Shear steel is made by taking a high heat on blister steel and hammering it thoroughly. Double shear steel is made by cutting up shear steel, piling it, heating it, then hammering again. The best shear steel must be made from the best wrought iron. The shear steels are very useful on account of their toughness and the ease with which they can be welded to iron, and, when of good quality and well worked, they will hold a very fine edge.

Crucible steel is made by melting in a crucible either blister steel, or blister steel and wrought iron, or wrought iron and charcoal, or wrought iron and scrap steel, or, in short, a great variety of mixtures, which depend on the quality of steel to be produced.

Crucible steel can be applied to any purpose for which steel is used. Generally, it is better than any other steel—that is to say, crucible steel made by melting blister steel and tempered to suit by mixing iron of the same grade in the crucible is always better than German or shear steel made from the same blister.

Bessemer steel is made by blowing air through melted cast iron, thus burning silicon and carbon out of the cast iron. After the silicon and carbon are burned out melted spiegeleisen or ferro-manganese is added to the charge. The carbon in the spiegel re-carbonizes the steel to the desired point, and the manganese unites with and removes the oxygen which the air used leaves in the steel.

Open-hearth steel is made by melting, in a very hot furnace, a charge of pig iron. To this melted iron, which is called the "bath," is added either wrought iron, or scrap steel, or iron ore, and the whole is kept hot until all is melted. The wrought iron, or scrap, or ore reduces the carbon and silicon in the bath to such proportions as are desired in the steel.

Bessemer and open-hearth steel are much alike in quality. They are used mainly for rails, boiler plates, ship plates, bridge and other structural purposes, and machinery. The better qualities are also used largely for springs. The best spring steel, like the best tool steel, is simply that which is made from the best material. Quality of material, chemically speaking, being equal, the best spring steel is that which is made from crucible cast steel, as the crucible process is less crude than either of the others.

REPORTS OF ENGINEERING SOCIETIES.

AMERICAN SOCIETY OF CIVIL ENGINEERS.—The Society held their thirteenth annual Convention at Montreal, Canada, June 15th. In addition to the discussions upon the papers of the past year, the following papers were presented to the Convention:

Re-enforcement of the Anchorage and Renewal of the Suspended Structure of the Niagara Railroad Suspension Bridge: L. L. Buck.

The Stability of Tunnels in River Silt: Ashbel Welch.

Repairs of Masonry: O. Chanute

Experiments upon Strength of Wrought Iron Columns: T. C. Clarke.

On Weights and Measures: Charles Latimer.

Comparative Economy of Light and Heavy Rails: Ashbel Welch.

ENGINEERS CLUB OF PHILADELPHIA.—Record of Meeting, May 21st.—A paper on the Comparative Anatomy of Locomotive Engines was read by Mr. Geo. Burnham, Jr.

Prof. Haupt replied to Dr. Chance's comments on the benefit to be derived from diagonal thoroughfares.

Dr. Chance concludes, that whilst diagonals "would pay, financially," and should be introduced into every proposed plan of a city, yet they would increase the density and hence be objectionable. To this Prof. Haupt answers that additional avenues, to a limited extent, would open new air channels, admit more sun light into the dwellings, would not practically increase the density of population, would concentrate business,—enabling it to be attended to with much less loss of time and trouble,—and would practically extend the radius of the city to an extent equal to the distance saved, thus enabling the populace to go that much farther into the suburbs without increase of time or expense.

In brief, both from a sanitary point of view and financially, the proposed system would be a gain to the private citizen, to the business man, to the property owner and to the city, and the original estimate of benefits to be conferred, instead of being excessive, are believed to be far below the actual results which would follow the introduction of such a system

Mr. Rudolph Hering exhibited and explained a number of ancient and modern maps of Eu-

ropean and Asiatic cities, showing the method of their development.

Mr. Chas. A. Ashburner, of the State Geological Survey, has adopted the Amsler's Planimeter for the estimation of the mine areas in the survey of the Anthracite Coal Fields of Penna. He has subjected the accuracy of the instrument to a severe test. In computing areas in square inches of map surface, it was found that the maximum error was one-quarter of one per cent. In computing areas on maps of large scale the average error of the planimeter is believed to be less than either the minimum error of a careful compass survey or of an accurate plot.

June 4th.—Prof. L. M. Haupt read some notes on Cobble Stone Pavements, commenting on the great variety of size and form, as exhibited in the streets of this city. He gave extracts from the Ordinance of June 12th, 1868, specifying the size of such stones to be not more than "9 or less than 6 inches in depth, or showing a greater length of face than 7 or less than 4 inches"—and then stated the characteristics of one "cobble" which he took up, weighed and returned to its position. It was found to be 38 inches long by 25 wide by 10 deep;—to contain 4 cubic feet and to weigh 625 pounds, or one hundred times the weight and volume of the average stone as specified.

The form of cobble stones, being spheroidal, was also shown to be unfavorable to resist the forces which act upon them, and the practical absence of friction between the surfaces of contact render them unstable and entirely unfit to perform the duties required of a good pavement.

The porosity of such a surface covering, admitting water freely to the substructure of gravel, loam and clay, which expands forcibly in Winter, raising the entire surface, and shrinks away under the influence of the spring temperature, leaving the stones unsupported, was mentioned as another element of destruction and expense; and altogether it was concluded that the cobble stones were unstable, unsafe, unclean and ultimately more expensive than well laid Belgian blocks having concrete foundations.

Prof. Haupt also read a brief discussion on the methods of expressing the scales of maps and of determining their relations to each other, so as to avoid ambiguity, giving a sample formula applicable to any case.

Mr. Frederic Graff exhibited an ancient map of Philadelphia, made to show the location of the early hose companies of the city.

THE NEW YORK ELECTRICAL SOCIETY.—The New York Electrical Society was organized March 2d, 1881, for the advancement and spreading of Electrical knowledge.

These objects will be attained by the holding of periodical meetings, and the founding of a reading room, library and laboratory.

The Society meets on the first and third Thursdays of each month in the Chemical Lecture Room of the Cooper Union.

The following are the officers:

President, F. W. Jones; Vice-Presidents, Geo. B. Scott, P. H. Van der Weyde, Gerritt Smith, W. J. Dealy, Geo. A. Hamilton, Geo. G. Ward; Secretary, J. W. Moreland; Treasurer, M. Brick; Executive Committee, F. W. Jones, Geo. B. Scott, J. W. Moreland, G. L. Wiley, E. C. Cockey, C. S. H. Small.

There are 240 members.

ENGINEERING NOTES.

MEASURING ELECTROMOTIVE FORCE.—A new method of measuring the electromotive force of a battery by means of the torsion balance has been applied successfully by M. J. B. Baille, and the results communicated to the French Academy. To obtain good indications the perturbations due to the trembling of the ground and the electricity of the atmosphere had to be eliminated by mounting the instrument on solid pillars, and enclosing it in a metal case connected to the earth. Variations of temperature are also guarded against by a thick jacket of wood shavings around the balance. The balance employed consisted of a long torsion wire of annealed silver, carrying at its lower end a lever terminated by two gilded copper balls. The lever was suspended at an equal distance from four similar fixed balls placed at the corners of a rectangle, each diagonal pair of balls being connected by wire. The lever was connected by the torsion wire to the positive pole of a standard battery, the other pole being to earth. One pole of the battery to be measured was then connected to the fixed balls, the other pole being to earth, and the deflections of the lever observed on a scale of clear glass placed about 10 ft. from the lever. Coulomb's well-known formula for static charges gave the electromotive forces of the cells measured. The following numbers represent the potential of an element of the kind described, that is the quantity of electricity spread upon a sphere of 1 centimeter radius, in electric units.

	Open circuit.
Voltaic cell	0.03415
Zinc, sulphate of copper, copper cell...	0.02997
Zinc, acidulated water, sulphate of copper	0.03709
Zinc, salt water, carbon, peroxide of manganese...	0.05282
Zinc, salt water, platinum, chloride of platinum...	0.05027
Zinc, acidulated water, carbon, nitric acid	0.06285

IN a pamphlet on the London water supply, and speaking of well water from the chalk, Mr. J. Lucas, F. G. S., says:—It would be utterly rash to count upon more than an average of 6 in. of rain passing into the underground water systems. Then if a mean quantity of 6 in. be supplied annually to the chalk, and it were in contemplation to inquire whether the whole water supply of London could be supplied from the chalk of the Thames basin, the question would be answered in this way—It would, at this rate, take the whole supply of 588.232 square miles to furnish 140,000,000

gallons per day—if it were possible to obtain the whole. Assuming, before making a proper survey, that only one-third could be taken, then an area of 1767 square miles would be required to furnish the same quantity, but the Thames basin, as far east as the western boundary of the Medway basin, and exclusive of the Lea, contains only 1265 square miles of chalk. The Lea basin contains about 250 square miles of chalk, which brings up the total to about 1500 square miles of chalk in the Thames basin; therefore, if after a close survey these figures could be substantiated, the chalk of the Thames basin could not supply the whole requirements of the metropolis for all purposes, but if the whole area of 1500 square miles were brought under contribution so as to yield one third of its total supply, it would in that event fall sho.t of the present total requirements of the metropolis.

THE FINANCIAL ASPECT OF THE CHANNEL TUNNEL PROJECT.—Precedents as to cost would hardly justify an engineer in estimating a tunnel under the channel at less than £200 per yard, or £352,000 per mile—being less than half the cost of the metropolitan lines, of the cost of which, however, we must remember that the price of land formed an important, though undistinguished portion. To pay 5 per cent. on £350,000 per mile requires a traffic of about £35,000 per mile per annum, or more than five times as much as the South-Eastern Railway. No English railway approaches the quarter of this figure with the exception of the two metropolitan lines, which take respectively £38.600 and £34,300 per mile. These, it is well known, are entirely exceptional cases, fed by constant local urban traffic, with stations little more than half-a-mile apart. In the Channel tunnel there can be no local traffic Generally speaking, it will be only the through passengers from London to Paris, and *vice versa*, who could be depended on to feed the line. Taking all things in the most favorable light, we have to consider whether a traffic equal to that of the Metropolitan District line is rationally to be expected, under any circumstances, to arise between Dover and Calais.—*Builder*.

FAURE'S ACCUMULATOR.—Among the important advances in electrical engineering may probably be reckoned the new *Accumulator* of M. Faure, although the performance of the apparatus thus far seems hardly to justify the enthusiastic predictions of some of the French journals.

The accumulator is an improvement upon, although a slight modification of, Plante's Secondary Battery. Lead plates covered with minium form the electrodes of the accumulator, and these are immersed in water acidulated with sulphuric acid. When an electric current is passed through the apparatus, the minium is brought to the condition of peroxide on the positive electrode, and reduced to metal on the negative. It is charged as a *quantity* and discharged as an *intensity* battery. It may be transported long distances after charging, and allowed to remain unused for considerable periods without serious loss of charge.

A Faure Accumulator, weighing seventy-five kilograms (165 lbs), it is claimed will perform the work of one horse power for one hour. It is proposed to apply it at once to electric lighting.

IRON AND STEEL NOTES.

DEPHOSPHORIZATION IN FRANCE. — Mr. Francis Saur writes: "The Thomas Gilchrist process is not very successful in the east of France, and its application has met with serious difficulties. The largest concern in that region is actually in a very bad way. There the dephosphorization is direct. Sometimes 500 tons of good products are manufactured (a little too soft, by the way). Then, suddenly, the working goes wrong. Some castings stay in the ladle, others in the converter. This information, coupled with the recent trials of dephosphorized rails made at Creusot, throws a peculiar light upon the matter. In the East, as at Creusot, manganese appears to be the remedy; but, then, where is the economy of the process ? The question moves always in the same circle."

PRODUCTION OF THE IRON AND STEEL WORKS OF THE UNITED STATES. —The total production of the iron and steel works of the United States in the census year 1880, was 7,265,140 tons; in 1870 it was 3,655,215 tons; increase, 3,609,925 tons, or 98.76 per cent. The following table shows the production of each branch of our iron and steel industries in 1870 and 1880, with the percentage of increase or decrease in the latter year.

Iron and Steel Products.	Census year 1870. Net tons.	Census year 1880. Net tons.	Percentage of increase in 1880.	Percentage of decrease in 1880.
Pig iron and castings from furnace	2,052,821	3,781,021	84	—
All products of iron rolling mills..........	1,441,829	2,353,248	63	—
Bessemer steel finished products..............	19,403	889,896	4,486	—
Open-hearth steel finished products.	—	93,143	—	—
Crucible steel finished products..............	28,069	70,319	151	—
Blister and other steel	2,285	4,956	117	—
Products of forges and bloomaries...........	110,808	72,557	—	35
Total........ ...	3,655,215	7,265,140	99	—

Of the pig iron and furnace castings produced in the census year 1880, there were produced with cold-blast charcoal, 79,613 tons; with hot-blast charcoal, 355,405 tons; with anthracite, 1,112,735 tons; with bituminous coal and coke, 1,515,107 tons; and with mixed anthracite and coke, 713,932 tons The furnace castings amounted to 4,229 tons. The total production was 3,781,021 tons, of which 12,875 tons were spiegeleisen.

GEOGRAPHICAL DISTRIBUTION OF THE IRON AND STEEL INDUSTRIES OF THE UNITED STATES.—The whole territory of the United States may be regarded as comprising four

grand divisions—the Eastern States, the Southern States, the Western States and Territories, and the Pacific States and Territories. Assuming that the Eastern States comprise all of the States lying north of Delaware and east of Ohio, that the Southern States comprise all of the late slaveholding States except Missouri, and that the other divisions require no explanation, we present the following comparative statement of the development of the iron and steel industries in each of the grand divisions in the census year 1880.

Grand Divisions.	No. of establishments.	Capital invested.	Hands employed.	Wages paid.	Net tons produced.	Value of all products.
Eastern States....	556	$149,507,461	82,842	$34,361,660	4,671,808	$192,696,010
Southern States..	218	29,145,830	20,595	6,261,344	649,153	25,353,251
Western States and Territories.	224	50,755,990	36,663	14,542,587	1,912,689	76,933,686
Pacific States and Territories....	7	1,562,603	878	311,194	31,490	1,574,738
Total United States.....	1,005	$230,971,884	140,978	$55,476,785	7,265,140	$296,557,685

In 1870 there were 25 States engaged in the manufacture of iron and steel. Of these, South Carolina does not appear in the statistics for 1880. Its total production in 1870 did not aggregate 500 tons. The iron industry in this State has been practically abandoned. Since 1870 three States have for the first time engaged in the manufacture of iron, namely, Colorado, Kansas, and Nebraska; also two territories, namely, Utah and Wyoming. Utah did not, however, make any iron in 1880. It made a small quantity in each of the years 1874, 1875, and 1876, and it will make a larger quantity in the near future. California and Washington Territory have made arrangements since the close of the census year 1880 to manufacture iron. New Hampshire made iron many years ago, but it does not appear in the statistics for 1870; it reappears in the tables for 1880. Oregon and Texas each built a blast furnace in the decade preceding the census year 1870, but they did not make any iron in that year; they appear, however, in the statistics of production for 1880. The District of Columbia once had a blast furnace in operation, but in 1870 it had no iron industry whatever; in 1880 the United States Government owned and operated a small rolling mill at the Washington Navy Yard. Minnesota appears in 1880 for the first time among iron-manufacturing States, but its statistics relate only to the preparations that have been made to embark in the business. Thirty States, the District of Columbia, and Wyoming Territory actually made iron in 1880.

PRODUCTION OF ALL THE STATES IN 1880.

States.	Production, 1880.	Rank.	States.	Production, 1880.	Rank.
Pennsylvania..	3,616,668	1	Delaware........	33,918	19
Ohio...........	930,141	2	Kansas....	19,055	20
New York. ...	598,300	3	California........	14,000	21
Illinois.........	417,967	4	Maine.......	10,866	22
New Jersey....	243,860	5	Territory of Wyoming..........	9,790	23
Wisconsin......	178,935	6	Rhode Island....	8,134	24
West Virginia .	147,487	7	New Hampshire..	7,978	25
Michigan	142,716	8	Massachusetts.		
Massachusetts.	141,321	9	Vermont.........	6,620	26
Missouri	125,758	10	Colorado.........	4,500	27
Kentucky......	123,751	11	Oregon	3,200	28
Maryland......	110,934	12	Nebraska........	2,000	29
Indiana........	96,117	13	Texas..	1,400	30
Tennessee......	77,100	14	North Carolina..	439	31
Alabama.......	62,986	15	District of Columbia.............	264	32
Virginia	55,722	16	South Carolina..	—	—
Connecticut....	38,061	17			
Georgia........	35,152	18			

RAILWAY NOTES.

A MOST important railway item, particulars of which have never been collected for any line in the United Kingdom, is—Mr. Green remarks, in a recent paper on light railways, read before the Institution of Civil Engineers, Ireland—the number of passengers per carriage mile. On the French lines it averages 9.24, varying with the classes ; the weight of carriages per seat is 517 lbs., but the real weight of carriages per passenger, allowing for empty seats, is 1632 lbs., or 1881 lbs., dividing the weight of the brake van among the passengers. The weight of vehicle, reduced in construction to double the weight per passenger, is exaggerated in practice to eight or ten times the same weight. To obtain the gross dead weight it is necessary to also add a proper proportion of the weight of the engine and tender; and taking into account trains with two engines, empty running, and bank engines, it is found that the engine mileage exceeds the passenger-train mileage from 3 to 5 per cent. Unfortunately, the passenger trains cannot be separated from mixed trains carrying high-speed goods—*i. e.*, luggage, carriages, horses, &c.—but in such cases apportioning the weight of engine and tender—assumed to be two-thirds full on an average—between the passengers and high-speed goods, the total dead weight is 17 and 10½ times the paying load respectively, while on the new systems the result is more unfavorable, the numbers being 22 and 14 respectively. On one of the Spanish railways, for each ton of passengers, the weight of vehicles run was 9.18 tons, or 18.98 including the engine.

IN reference to the relative value of steel rails and iron rails, the following remarks of the chairman at the shareholders' meeting of

the North-Western Railway on Saturday are worth reproducing:—"They had nearly completed the whole of the work of relaying the road with steel rails both on the main line and branches, and they were deriving very great benefit this half-year from the economy which the introduction of the steel rail had produced. Going back to 1874, he found that the cost of relaying the line was £454,000 for materials alone, while in 1880 the total cost of relaying the line had been only £176,000. No doubt a very considerable portion of this difference was owing to the change in the cost of rails. Formerly the cost was much larger, but the average cost in the past half-year was £4 18*s.* 6*d.* per ton. When, however, they came to compare the number of miles relaid, he found that about 1875 and so forward they laid from 211 to 220 miles each year, whereas last year they had only needed to relay 150 miles. The question was, How long would that continue? He believed he told them once before that this year and last year were somewhere about an average of the future, but they did not feel very clear on that point, and they required a little more experience on the matter. He once told them that they put down some rails which weighed 84 lbs. to the yard, and they took them up at the end of sixteen years, when they weighed 59 lbs., but since then they had taken up some which weighed only 51 lbs. They never had any iron rails which wore away to a lower point than 74 lbs., so that, although the steel rails were lasting longer, they were wearing a certain quantity away each year; and they had therefore considered it prudent not to bring into division in the revenue the profit they made on the old rails a year ago."

ORDNANCE AND NAVAL.

THE NAVY IN 1881.—The Naval Estimates for the coming financial year were announced in the House of Commons on March 18th, by Mr. Trevelyan, the Secretary to the Admiralty. It is greatly to be hoped that when the separate votes come forward for discussion, the true condition of the Navy—a condition fraught with danger to the country—may be exposed in the House, by those naval officers and other critics who place the safety of their country before the convenience of party finance. That the condition of the Navy is serious will be abundantly evident to any one who takes the trouble to carefully study Mr. Trevelyan's speech. It is now perfectly clear that the shipbuilding policy of the present Board is dictated by precisely the same motives as was the policy of the late Conservative Board, as well as of the preceding Liberal Administration, a want of moral courage to come forward and tell the country the true condition of things, and to ask for the requisite funds to make the whole Navy really effective, because of the supposed unpopularity which increased estimates would entail.

The policy of the present Admiralty differs only in detail from that of its predecessors. When Mr. Ward Hunt came into power he found that the Liberal Administration before him had swelled their surpluses by allowing a large proportion of their ironclads to become ineffective from want of repairs to ships and boilers. During his administration, and that of his successor, Mr. W. H. Smith, this defect was remedied, so much so that Mr. Trevelyan tells us that we have now "actually 41 ironclads with their boilers in effective condition." But the Conservative Board failed in another and equally important duty. They found the task of maintaining the existing Navy to be so expensive, that they feared to ask the country for funds to build new ships as fast as they were required to keep pace with foreign rivals. Though they commenced many new vessels they finished but few. The Inflexible has been some six years under construction, and is not yet at sea, and of many other of their vessels it may safely be predicted that they will be out of date before they are completed. Even the Inflexible herself, the most powerful of our ships of the line, is known to be inferior in size, in armor, and in armament to the first-rate ironclads of two foreign navies. The present Board, having found the dockyards filled with partly-finished vessels, propose to complete them; but, on the other hand, they shelve altogether for the present the most important duty of commencing the construction of first-class ships of the line which shall be able to hold the seas against all comers. This deliberate omission will be severely felt in a year's time, when any ships now commenced should be ready for sea, and when we may confidently expect that the French and Italian navies will be even more formidable rivals than they are at present.

The actual new work which it is proposed to carry out during the coming year is as follows: The Agamemnon and Ajax are to be completed for sea at Chatham, and the Conqueror, an improvement on the Rupert, will be three-quarters finished. It is hoped also that the Polyphemus ram will be ready for sea by the end of the year. The sister ships, the Colossus and Majestic, building respectively at Portsmouth and Pembroke, are each to be advanced a fourth, and the Collingwood, which is described as the youngest device of the late Board, will have the first serious work done upon her. The late Board has now been out of office for a twelvemonth, and it is certainly a curious commentary on the energy of their successors that the first serious work on this ship should only now be in prospect. Not until the stress of these unfinished works is off his hands does the present First Lord intend to finally determine the type of the first-class ironclad of the future. Judging from past experience we may conclnde that another year will then elapse before he asks Parliament for funds to commence these ships. Delays will probably then arise, on account of some new necessity for the repair of the existing fleet; but granting that the new ships will not take longer to complete for sea than the Inflexible, viz., six years, a decade will nearly elapse before this country is in a position to meet the existing Italian ironclads.

Turning from the question of first-class ironclads to that of swift cruisers for the protection

of commerce, we find that at the present moment we have only eleven cruisers having a greater speed than 14 knots to protect one half of the entire mercantile marine of the world in case of war; and in this number are included the Mercury and Iris, which are, properly speaking, not cruisers at all, but swift despatch boats. The late Board attempted to improve this state of things by ordering the building of three fast cruisers, known as the Leander class. These three vessels are being built by private contract on the Clyde. The present Government intend to lay down a fourth Leander at Pembroke, but as this ship is only to occupy the spare time of the two hundred extra men at work on the ironclads, it will doubtless be some time before any serious work is commenced on her.

We now come to the most interesting proposal of the Government, viz., a class of cruiser which shall have a speed of 16 knots; a coal supply of 900 tons; auxiliary sail power; copper sheating, twin screws, and a belt of steel-faced armor 10 in. thick with 10 in. backing extending 140 ft. amidships, 3 ft. above water and 5 ft. below, so as to protect the boilers and machinery; also a steel conning tower, and an underwater deck, plated with 3 in. steel. covering the whole ship where not protected with side armor. The proposed length is 315 ft.; the extreme breadth 61 ft.; tonnage about 7,300, and engines of 8,000 horse power. The armament is to consist of four 18 ton 9.2 in. breech-loading guns of the new type, mounted *en barbette*, and six 6 in. breechloaders. In addition to the above, the vessels of the new type are to be provided with boat, field and machine guns, torpedoes, and probably with two torpedo boats. In the words of Mr. Trevelyan, she is intended to "rank high among cruisers, and high among second-class ironclads."

It is intended to lay down two such vessels this year at Government establishments, and later on to let out a third to contract. These vessels, if they at all combine the numerous advantages claimed for them, will undoubtedly be most useful additions to the fleet. The above list comprises all the principal features of the year's programme; but before quitting the subject, we must warn our readers not to be too sanguine that, modest as they are, these proposals will ever all be really carried into effect. The Board of Admiralty occasionally enliven their yearly statement by glowing promises to build cetain much-wanted ships for which they obtain the funds. The manœuver serves its purpose; it undoubtedly makes the programme of shipbuilding look effective, but sometimes it happens that the ships are not built. Sir E. J. Reed, a strong supporter of the Government, drew attention to this circumstance in language of impressive severity. It appears that, last year, the House was required to vote the funds for the construction of three new ironclads, to be laid down at the Chatham, Portmouth and Pembroke yards, and these have disappeared altogether from this year's programme. Thus, to use the words of Sir E. Reed, "the Government put ships into their programme, and took them out of it, at their pleasure, without consulting the House on the subject at all."

Another subject of the greatest importance is the arming of the fleet. We have it now admitted for the first time officially that our existing guns are obsolete. Mr. Trevelyan tells us that at the present moment there is not a single heavy breechloading gun mounted in any of our ships, but that by the end of next year a very substantial beginning would have been made towards arming the fleet with breech-loaders. In another place he states that the 18-ton guns of the new armored cruisers will be more powerful than the Woolwich guns mounted in the Thunderer, which, as is well known, weigh 38 tons. The ex-First Lord, Mr. Smith, makes the remarkable admission, that however good our Woolwich guns may be, there could be no doubt that the naval guns of England were inferior to the new guns on board the German, French and Russian ships, and that the Krupp gun was certainly superior to anything which we now possessed on board our fleet. Again, Mr. Stuart Rendel, whose practical acquaintance with the manufacture of heavy artillery cannot be disputed, tells us that, as far as armament was concerned, the whole British Navy might be considered to be at half power. These are serious admissions, but they fully bear out what we have ourselves in these pages unceasingly pointed out for the last ten years. It is with sincere pleasure that we acknowledge that the Government has at last arrived at a state of knowledge on this subject to which other people had attained years ago. Being, however, thus late in the day possessed of this information, it is little short of criminal folly to postpone for a single day longer than is absolutely necessary, the re-arming of our fleets and of our land defences. And we think that the Government can hardly be aware of its responsibilities, and of the duties which it owes to the country, when the representative of the Admiralty in the House of Commons calmly speaks of the end of next year, that is practically the commencement of the year 1883, as the period when a substantial *beginning* will have been made towards re-arming the fleet. We should like very much to know what guarantees the Government possesses that it will not before that period arrives be called upon to confront the fleets of our neighbors with vessels which, on its own showing, are wholly armed with obsolete weapons, and which are therefore incompetent effectually to defend the country. Now that the truth is within their knowledge, the policy of the Admiralty in this respect must be pronounced as one which invites humiliation and which courts disaster.—*Engineering.*

Torpedo Vessels.—A paper on "The Further Development of the Thorneycroft Torpedo Vessels" was read, recently, at the Royal United Service Institution, by Mr. John Donaldson, M.I.C.E. When, four years ago, he delivered a lecture on the construction and armament of torpedo boats, Mr. Donaldson said he described the Scandinavian type of boat, the Dutch, Italian and French types, and

the *Lightning* type. These types had all gradually been developed into two distinct groups, comprising those attached to and carried by larger vessels, and those sufficiently large to act independently and to a certain extent to keep the sea. Having explained with the aid of diagrams the improvements which had been effected in the construction and fitting of boats of these two classes made by Messrs. Thorneycroft & Co. for our own and other Governments, he stated that the French had at present between 30 and 40 torpedo boats at Cherbourg alone, and an admirable system of training, under which most of the war marine were instructed in the use of torpedoes and torpedo boats. Looking forward, he suggested as improvements desirable in the larger or first-class torpedo boats, protection in front by means of 3-16 inch plates below deck and ¼-inch plate above deck in front of the conning tower, at such an angle as would prevent penetration at a distance of 400 to 1,000 yards; armament with machine guns and with the spar torpedo as in the case of the second-class boats, and a protection for the screw propeller.

THE ITALIAN MERCANTILE MARINE.—A correspondent writes: "The Italian parliament will shortly be asked to consider a project for uniting the two important steamship companies of Florio and Rubatino, so as to form one great Italian organization. The intervention of parliament would be merely formal, were it not that the law only allows the directors of such companies to remain two years in office, and the combined company will ask for a term of at least fifteen years. This long term is explained by a bill simultaneously presented to parliament by Signor Baccarini, the minister in connection with the intended fusion, authorizing a contract to be entered into by which, during fifteen years, the transport of 200,000 tons of coal from English to Italian ports would be given to an Italian company, which, on its part, would undertake to construct fifteeen large steamers. It is clear that the advantages already enjoyed by the Florio and Rubatino companies through the subsidies they receive for carrying the mails, would be considerably increased by the receipt of three and a-half million lire for the transport of those 200,000 tons of coal. It will be a blow to British shipping, which at present monopolizes the coal trade from England to Italy. Considering the advantages held out, it is very probable that the money will be found for the construction of the fifteen ships demanded. It remains to be seen, however, whether the free traders in the chamber of deputies, and they are not inconsiderable in number, will view the protection thus asked for Italian shipping favorably. Another question is whether the fifteen steamers, for the building of which the State would give an indirect subsidy, should be constructed abroad, or whether the company would undertake to have all or part built in Italy, and, if so, whether its dockyards have sufficient capacity for the work. Considering the great depression at present existing in the Italian mercantile marine, and the general readiness of the government to aid in its revival, the project may after all be favorably received, for it imposes on the company an addition to the Italian mercantile fleet of fifteen large steamers. Not having before me the exact tenor of the ministerial project, it is impossible to say in what manner the government will protect itself against the disadvantage of a fixed freight."

BOOK NOTICES.

PUBLICATIONS RECEIVED.

PRELIMINARY REPORT UPON THE IRON AND STEEL INDUSTRIES OF THE UNITED STATES. By James M. Swank. Philadelphia: American Iron and Steel Association.

CENSUS BULLETINS, 150 to 156, inclusive. Published by Department of the Interior, Washington.

TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS. RAIL PATTERNS. By A. L. Holley.

SPECIMEN MAPS FROM JOHNSTON'S ATLAS. Edinburgh: W. & A. K. Johnston.

ROORKEE HYDRAULIC EXPERIMENTS. By Captain Allan Cunningham, R. E. Vol. I.—Text. Vol. II.—Tables. Vol. III.—Atlas. Roorkee: Thomason College Press.

ANNUAL REPORT OF THE CHIEF ENGINEER OF THE WATER DEPARTMENT OF THE CITY OF PHILADELPHIA FOR 1880. By Wm. H. McFadden, Chief Engineer.

THE WORKSHOP. No. 6. PLATES No. 36—42. E. Steiger & Co.

PORTSMOUTH DOCKYARD EXTENSION WORKS. By Charles Colson, A. M. I. C. E., and Christian Hendrick Meyer, A. M. I. C. E. London: Published by Institution of Civil Engineers.

MODERN ARCHITECTURAL DETAILS. Part 9 New York: Bicknell & Comstock.

WORKING DRAWINGS; HOW TO MAKE AND HOW TO USE THEM. By Lewis M. Haupt, C. E. Philadelphia: Jos. M. Stoddardt & Co. For sale by D. Van Nostrand. Price,

In this little treatise the rudiments of descriptive geometry are presented in a manner that can readily be taught to pupils who are beginning mechanical drawing.

It is believed by the author, and with good reason, that the higher grades of our grammar schools can readily accomplish all that is comprised in this book. Moreover, when this short course is fairly mastered, the pupil will have sufficient knowledge of projections to construct working drawings of many objects, and he will have gone far towards the acquirement of a good practical knowledge of the various branches of draughting.

It is designed to follow this book with another for more advanced pupils.

COUR D'EXPLOITATION DES MINES. Per Amedee Burat. Paris: J. Baudry. For sale by D. Van Nostrand. Price,

This is the third edition of a well-known treatise. The text, including the supplement, extends over 736 royal octavo pages, while the plates fill a quarto atlas of 138 pages.

The topics treated are—General Methods of Working Mines; Working Coal Mines; Galleries and Tunnels; Draining and Ventilating; Compressed-Motors; Underground Transportation; Hoisting and Pumping Apparatus.

The supplement describes the improved methods of ventilating and hoisting and draining, as exhibited and worked in 1880.

The illustrations and text are excellent.

A PRACTICAL TREATISE ON THE MANUFACTURE OF STARCH, GLUCOSE, STARCH SUGAR AND DEXTRINE. From the German of Ladislaus von Wagner and other authorities. By Julius Frankel. Edited by Robert Hutter. Philadelphia: Henry Carey Baird & Co. For sale by D. Van Nostrand. Price,

The important industries indicated by the above title, seem to be treated with special reference to the practical side of the several topics. Beginning with the physical and chemical properties of starch, the author proceeds in a second section to describe, with great care, the processes of manufacture of starch from potatoes, wheat, corn and rice, each separately, and concludes with the methods of distinguishing the varieties and detecting adulterations.

Starch sugar is treated in similar manner. The history, terminology, physical and chemical properties cover nearly forty octavo pages. The various methods of manufacture forming the second section of "Part II.," constitute the more important portion of the work, and the detailed descriptions of the processes are proportionately expanded.

This section includes also the methods of testing, and the applications of the product.

Dextrine is the subject of Part III., and receives the same kind of treatment; the properties, manufacture, tests and uses being successively treated.

The illustrations throughout are of a good quality, and in quantity are all that the text requires.

A MILITARY DICTIONARY AND GAZETTEER. By Thomas Wilhelm, Captain of Infantry. Philadelphia: L. R. Hamersly & Co. For sale by D. Van Nostrand. Price,

The title of this work probably sufficiently explains its character, but its scope can only be fairly estimated from the schedule of its contents. It includes ancient and modern military technical terms, historical account of the different tribes of Indians, accounts of celebrated battles in all ages, and a concise explanation of all heraldic terms.

An appendix contains the articles of war.

MISCELLANEOUS.

TIMBUCTOO is only a collection of insignificant huts, and the great "basin" of the Sahara desert, which it was proposed to flood by the waters of the Mediterranean, and so make another inland sea, is no basin at all, but a plain, elevated considerably above the level of the Mediteranean. These are the revolutionary accounts brought back by Dr. Letz, a German traveler, just returned from a journey from Tangier to Timbuctoo.

ARTIFICAL SEASONING OF TIMBER.—To prepare timber for the sounding boards of musical instruments, so that they are not influenced by variations in temperature and atmospheric changes generally, Mr. C. Rene, pianoforte manufacturer of Stettin, Germany, has devised a plan by which he makes use of the property of oxygen, particularly of that ozonized by the electric current, to artificially season the timber. The first impulse to experiments being carried out in this direction was given by the well-known fact that wood, which has been seasoned for years, is much more suitable for the manufacture of musical instruments than if used soon after it is thorougly dried only. Mr. Rene claims that instruments made of wood which has been treated by his oxygen process possess a remarkably fine tone, which not only does not decrease with age, but as far as experience teaches improves with age as does the tone of some famous old violins by Italian masters. We are further told that the sounding boards made of wood prepared in this manner have the quality of retaining the sound longer and more powerfully. A number of pianos manufactured at Mr. Rene's works, and exported to the tropics several years ago, have stood exceedingly well, and seem in no way affected by the climatic dangers they are exposed to. While other methods of impregnating wood with chemicals generally have a deteriorating influence on the wood fibers, timber prepared by this method, which is really an artificial ageing, becomes harder and stronger. The process is, we understand, regularly carried on at Mr. Rene's works, and the apparatus consists of a hermetically closed boiler or tank, in which the wood to be treated by the process is placed on iron gratings; in a retort, placed by the side of the boiler and connected to it by a pipe with stop valve, oxygen is developed and admitted into the boiler through the valve. Provision is made in the boiler to ozonize the oxygen by means of an electric current, and the boiler is then gently fired and kept hot for forty-eight or fifty hours, after which time the process of preservation of wood is complete.

LIGHTNING CONDUCTOR.—On the 6th instant, an interesting lecture was delivered at the Royal United Service Institution, by Captain James Bucknill, R.E., on the application of lightning conductors to buildings and magazines. The lecturer, with the assistance of capital diagrams, explained the action of thunder storms, and showed that they were least to be dreaded over non-conducting areas. He argued forcibly against any reliance being placed on the safe-circle theory, which has been revived of late both in this country and in France. Much was said in favor of iron

rather than copper for conductors, (*a*) because some samples of copper are so deficient in conducting power as compared with the best samples of copper, and iron being more constant in its conducting power; (*b*) because equal conducting power can be purchased in each for the same money, and there being a greater mass in the iron conductor, it is heated less by the same current of electricity; (*c*) because the fusing point of iron is much higher than that of copper; (*d*) because it is less liable to be stolen, or accidentally damaged. On the other hand, it was admitted that the small copper ropes and bands are less objectionable from an architectural view, because less observable It was urged that pliable wire ropes are better than bands, rods, pipes, &c., because the conductors can be continuous and without joints. For general purposes wire ropes weighing 6 lbs. per yard if of iron, and 1 lb. per yard if of good copper, were considered sufficient; and in the event of a conductor being carried up one side of a building along the roof and down the other side, a reduction of one-half in the conductivity was recommended if two good earth connections are provided. For a monument or spire, therefore, a 6-lb. iron-wire rope and one earth connection, and for a dwelling house a 3-lb. iron-wire rope and two earth connections, are recommended. Lofty rods were not advocated, but advantages were claimed for the multiple points. The very different amount of surface considered to be necessary by various authorities was stated, and this part of the subject was entered into very fully by the lecturer, some of whose arithmetical deductions were curious; especially those relating to the indifferent conducting power of water, as compared with the metals. The fact that the electrical resistance of copper and of water differ so greatly is brought home more thoroughly to our minds by the statement that a bar of water one yard long offers as much resistance as a copper bar of same diameter, and of a length equal to seven times the distance of the moon! Reasons were given for employing large earth connections, and for using coke or ashes as an enveloper and intermediary, their conducting power and low cost being such that they can be so used with very good effect. The lecturer, who was employed last summer in testing and inspecting a large number of the Government conductors on magazines, advocated that sliding joints should be discontinued, and that all joints, whether screwed, riveted, or otherwise, should, in addition, be soldered. Until this be done he stated his disbelief in the value of electric testing, but that with continuous conductors and properly constructed earth connections the electrical testing would at once become useful. An ingenious instrument was exhibited which had been designed by Captain Bucknill, for testing resistances not exceeding 11,000 ohms. The arrangement, which is very portable, combines a Wheatstone's balance, coils, galvanoscope, key, and terminals, with a small voltaic battery, which may or may not be added as desired. The whole forms an absolute testing arrangement, and the tests can be made quickly and without any difficulty. We propose, in a future number, to give a drawing and details of this apparatus, which is manufactured by Messrs, Elliott Brothers, Strand.

A New High-Speed Motor.—The Hon. R. C. Parsons has invented a new engine, which is manufactured by Messrs. Kitson & Co., of Leeds. Externally it consists of a closed cylindrical vessel, from one side of which the end of the crank shaft protrudes. The interior of the closed cylindrical vessel contains a steam engine having four single-acting cylinders arranged radially round the crank shaft, the center line of which is normal to the plane in which they lie. Mr. Parsons contents himself with a moderate speed for the reciprocating parts, viz., pistons and connecting rods. He does not allow for them a greater number of reciprocations than corresponds with, say, 450 revolutions per minute, and therefore keeps down the tendency to rattle, hammer, and disintegrate to a minimum. But he doubles the number of revolutions for the crank shaft by the simple expedient of causing the casting, forming the united four cylinders, also to rotate in the same direction as the shaft. Of course the casting referred to must be carefully balanced, but the radial arrangement makes this quite easy. And thus the high speed of 900 revolutions per minute is, it is claimed, attainable, and steadily maintainable, without noise, shake, undue wear and tear, or any known disadvantage beyond such as any other similar engine would be liable to when running at 450 revolutions. The object of the closed cylinder casing is obviously to collect the exhaust steam which clears itself away from the cylinders in succession the instant release takes place. It further serves the purpose of maintaining the temperature of the cylinders at at least 212°, and of enabling the exhaust steam, and any intermixed lubricants, to get at all enclosed moving parts. It also acts as a dust excluder and safety guard There is yet another new feature included in Mr. Parsons' engine. We have for some time become familiarized with the use of small pumps, attached to certain machines, for pumping oil or a soap and-water solution upon or under the cutting edge of a tool. The oil or solution afterwards flows away into a collecting reservoir, and is again utilized and re-utilized indefinitely. Mr. Parsons adopts this principle for lubricating the rapidly-revolving parts of his engine. He then makes sure of a continuous flow of oil at a sufficient pressure to keep apart the wearing surfaces, which ought, therefore, to remain cool and uninjured for any length of time, provided the small pump is kept in operation. The possible disadvantages which may attach to the new motor seem to us to be three fold, viz.: (1). It may prove to be heavy and expensive as to first cost, in proportion to power developed. There is obviously the cost of the cylindrical enclosing vessel, of the extra mechanism for rotating the cylinders, and of the oil-circulating machinery to provide On the other hand, double the power is gained by double the speed, and this will "cover a multitude of

sins." To credit there is also the bed plate and supports of some kind, which, but for the casing, would be necessary. (2). Like all single-acting engines, the pistons are working during half only of each revolution. This means extra weight and original cost per foot-pound of power developed, as compared with double-acting cylinders. (3). It cannot be an economical engine if the pistons be made to act inwards, because that would manifestly involve the usual long steam passages to convey the steam for the central distributing valve to the outer ends of the cylinders. The large obnoxious spaces thereby formed prevent all chance of economy. It is, however, not clear whether the steam may not now or might not possibly be made to act outwards in connection with the large surrounding exhaust chamber, and whether in such case large obnoxious spaces may not be used. It is understood that Messrs. Kitson & Co. are manufacturing this motor for Mr. Parsons, and that modifications have already been designed for other purposes as well as for driving dynamo-electric machines.—*Engineer*.

The Decimal System.—When Mr Ashton Dilke rose in his place in the House of Commons, on Tuesday night, to move "That in the opinion of this House the introduction of a decimal system of coinage, weights and measures, ought not to be longer delayed," he did so probably with a full sense of the opposition which this proposed change is sure to meet. The plausible way in which he supported his proposal, and the arguments which he used, have been tried before upon the British public, hitherto without success. That public, as represented in the House of Commons, in a kind of panic, have done many wise and many foolish things, but many useful measures and reforms have been carried and effected only after the most persevering efforts by their authors. Notwithstanding the official discountenance which Mr. Dilke's motion experienced, that gentleman may rest assured that the reform which he advocates is one which must, sooner or later, be adopted. It has the cordial support of the great majority of the scientific portion of the community. It is to be regretted that this country should, in this respect, be behind other nations who have changed their systems, but the very decided advantages which so simple a means of reckoning presents constitute an argument for its introduction which it is difficult to meet, and which will one day convince even so stubborn an animal as John Bull.

The Suez Canal.—There have been loud complaints on the part of shipowners regarding the general management of the Suez Canal, and especially the system of piloting vessels. Thus, in one case, it is stated that a certain vessel could only get a pilot who, not knowing any English, was necessarily unable to give intelligible orders. Hence, four days were consumed in getting from Ismaila to Port Said, the ship having grounded several times, and also got into collision with a steamer. What makes the case worse is, that pilot dues on the canal seem to be decidedly liberal, being £26 a day for the ordinary passage of forty-eight hours. These payments, however, are applied, it is stated, in great part to cover other contingent expenses. Another charge, amounting to £21, in the case of a vessel of 1211 tons, on the score of light dues, seems to be at all events extravagant; but any excess in this item is, it appears, the unearned perquisite of the Egyptian government. All this, in the case of a vessel of the size named, is in addition to the heavy tolls, amounting to £650. Inquiry into these matters would be highly desirable, especially as the undertaking has an international character, and in which this country has by far the largest interest. We gave, a short time ago, some approximate figures of the traffic that has passed through the canal in the past year. From official statistics now published, it appears that, in the course of 1880, 2017 ships passed through the canal, with a tonnage, according to official reckoning, of 2,860,448, but really amounting to 4,378,964 tons. The number of hands employed in the navigation was 128,453, the number of passengers 53,517. Of the 2,860,448 tons, official reckoning, 2,247,306 were British, 177,771 French, 75,820 Austrian, 124,083 Dutch, 71,039 Italian, 56,245 Spanish, 38,162 German, 29,607 Russian, 7,203 Turkish, 8,032 Egyptian, while 25,180 tons belonged to other countries.

An Electric Letter Post.—Improving upon the electric railway, Dr. Brunner von Wattenwyl has invented a similar railway by which, he believes, letters may be transmitted to great distances, as they are now sent to short distances in pneumatic tubes. Messrs. Siemens and Halske, of Berlin, have constructed a model of the inventor's apparatus, which was exhibited last week at the lecture which Herr von Wattenwyl delivered before the Scientific Club of Vienna. The lecturer proposes to place miniature lines of railway near or under the great railway lines, and to put these into communication with small electric locomotives, to which would be attached small wagons to take up letters. The letter post would run with more than railway speed, and would have the advantage of being independent of trains, and capable of being used at any time. The electric letter post exhibited during the delivery of the lecture was made to proceed along the rails at any speed required. The lecturer, after referring to the doctrine of the correlation of forces and its connection with his invention, pointed out that one of the chief advantages of the new power was that it was worked from the railway stations, and was not carried along the line by locomotives. It remains to be seen whether the invention is of such a nature as to enable it being put into practical operation.

VAN NOSTRAND'S

ENGINEERING MAGAZINE.

NO. CLII.—AUGUST, 1881.—VOL. XXV.

THE FUTURE DEVELOPMENT OF ELECTRICAL APPLIANCES.

By PROFESSOR JOHN PERRY, B. E., Assoc. M.I.C.E.

From the "Journal of the Society of Arts."

It had been my intention to introduce this subject to your notice by speaking of the great things physical science has already done for humanity. I assure you, that I had arranged a most effective harangue on this subject, touching on the Bacons, and Newton, and Boyle, and Watt, and Faraday, and Joule, and Thomson, showing that it was these men in their laboratories who opened the way for Stephenson, Wheatstone and Cooke, Gramme, Hughes, Edison, and Graham Bell. I meant to tell you how, in days gone by, a few Birmingham business men subscribed to give their townsman, Priestley, sufficient money to live upon while working at original research; and I felt able to prove so clearly to you, that it was for the good of the nation to provide scientific men with large laboratories, and to ensure them freedom from ordinary cares, that in the mere preface to my proper subject, I prepared an hour's lecture. Luckily, I remembered that you had all had opportunities of hearing about the benefits you owe to science; and I bethought me that you might even be tired of listening to truisms regarding endowment of research; truisms to members of the Society of Arts, but not so well believed in by the general public, and especially by that section of the general public which sees reason to lean on Mr. Ruskin, in whose nostrils the mere names of Watt and Stephenson are as the savory odors of the Thames at low water, and attends to the views of Sir John Ellesmere, who hated telegrams more than he disliked our common enemy. Men of this stamp may well think of the future with horror, for there is every sign that applied science is increasing the acceleration of the rate of its development. To such men I would say: Put a stop to laboratory work; set your faces against the endowment of research; root up the acorn if you would not in the future be plagued with the oak. The applied science of the future lies invisible and small in the operations of the men who work at pure chemistry and physics. These men do not know what will be the outcome of their labors. They often think that they sympathize with Mr. Ruskin; but you might as well ask a dram drinker to give up that which his soul loveth, as ask a man who has done real experimental work to give it up. I have often watched Sir William Thomson, to whom every object in nature is continually suggesting new ideas, new experiments; to whom every particle of brass scraped off by a file is a being full of complication, an object of interest, and a thing of beauty, and to whom the study of the bending of a bit of brass wire is a joy for ever. Sir William

Thomson believes in applied science, but such belief has really nothing to do with the delight which he and every other experimenter has in his work.

Now, electrical science has reached a position from which, on every side, hundreds of enticing paths lead forward into unexplored regions of nature. At every step in advance, the laboratory worker sees to right and left of him new and promising lines of research; and he feels that, for the work to be done, the present army of explorers is all too small and weak. But interesting as it might be to prophesy on investigations newly begun, it is rather my purpose, to-night, to take you upon the well-trodden ground prepared for us by Faraday, and Joule, and Thomson, to show you how, in one or two great lines of the applied science of electricity, certain fixed laws tell us about the future. I shall then speak of a few of the more recent discoveries.

Now, in the first place, you must remember that electricity is, to us, something that can be measured; although, unfortunately, to the ordinary telegraph operator, this is not the case. If you can imagine a mechanical engineer regarding a distance of a few inches as being equal to the distance of a few miles, or even of a few thousand miles; if you can imagine a grocer to confound an ounce of sugar with a ship's load of the same material, you get a too truthful idea of the vagueness, the general want of definiteness, in the notions of nearly all students of this subject until a few years ago, and, I am sorry to say, that much of this vagueness is still to be found even in modern scientific papers. Perhaps, when electricity is supplied to every house in the City of London at a certain price per horse power, and is used by private individuals for many different purposes, this vagueness will finally disappear.

To get exact ideas in any department of physics, we have one firm foundation to build upon, viz., that a certain amount of energy or power of doing work remains always the same, in whatever form it may appear. I have here various sources of electricity—a voltaic cell, a thermopile, a glass-plate machine, a magneto-electric machine, which may be turned by hand, and two dynamo-electric machines outside, which I can drive by means of a steam engine. As you know, there are many others. To all these, some form of energy is given, and they convert this energy, badly or well, into electric energy. The cell burns zinc; in the thermopile gas is burnt; to the three last machines mechanical energy is given; they all give out electrical energy. Now, how do we know that there is a production of electrical energy? Let us take any one of them—this voltaic cell, for instance. Some form of energy is given out, for you see that I can convert it into heat. (Experiment shown.) Here I take advantage of a property somewhat analogous to mechanical friction.

This thermopile is also generating electricity. To test this I connect its poles to the wire of a galvanometer, and the instantaneous deflection of the needle of the galvanometer tells me about the current. (Experiment shown.) Here is another proof that some kind of energy is traversing the wire connecting these two screws. The two wires are attached to an arrangement at the other end of the room; when I complete the circuits, whether I do it here or there, the bell rings. (Experiment shown.) You see that in this case the heat energy given out by this burning gas is converted partly into electrical energy, in which state it can be transmitted to a considerable distance, and there converted into mechanical energy, or into sound, or into any other form of energy. In these and other ways we can detect the existence of the electrical energy coming from all these generators, and measure its amount. Now, Joule's experiments tell us that any generator gives out exactly as much energy as is given to it, but much appears in the form of heat. All these generators get heated, and may be said, therefore, to waste energy. One great object of the inventors of such machines is, to give out as much as possible of the energy supplied to them in the shape of electrical energy. You must clearly distinguish between electricity and electrical energy. A miller does not merely speak of the quantity of water in his mill-dam; he has also to consider the height through which it can fall. A weight of one thousand pounds falling through a distance of one inch represents the same energy, that is, gives out the same amount of work in falling as one pound

through one thousand inches. A mere statement, then, of the quantity of electricity given out by a machine is insufficient; it is also necessary to state what is the height or difference of potential through which it is falling. The quantity of electricity in a thunder cloud is comparatively small, but the difference of potential through which this quantity passes when discharge occurs is exceedingly great. So it is with the two factors of the electrical energy developed by this glass machine. The quantity of electricity obtainable from this machine is comparatively small, but it is like a small quantity of water at an exceedingly great height, whereas, in all these other machines we have, in the analogy of the miller, a very great quantity of water and a very small difference of level. I put this water analogy before you because you have all more or less exact notions about water, and because, within certain limits, the analogy is a very true one. I have traced it more fully in the wall-sheet I.

WALL-SHEET I.

We Want to Use Water.	*We Want to Use Electricity.*
1. Steam pump burns coal and lifts water to a higher level.	1. Generator burns zinc, or uses mechanical power, and lifts electricity to a higher level or potential.
2. Energy available is, amount of water lifted × difference of level.	2 Energy available is, amount of electricity × difference of potential.
3. If we let all the water flow away through channel to lower level without doing work, its energy is all converted into heat because of frictional resistance of pipe or channel.	3. If we let all the electricity flow through a wire from one screw of our generator to the other without doing work, all the electrical energy is converted into heat because of resistance of wire.
4. If we let water work a hoist as well as flow through channels, less water flows than before, less power is wasted in friction.	4. If we let our electricity work a machine as well as flow through wires, less flows than before, less power is wasted through the resistance of the wire.
5. However long and narrow may be the channels, water may be brought from any distance, however great, to give out almost all its original energy to a hoist. This requires a great head and small quantity of water.	5. However long and thin the wires may be, electricity may be brought from any distance, however great, to give out almost all its original energy to a machine. This requires a great difference of potentials and a small current.

You will readily understand, then, that for some purposes it is necessary to have our electrical energy in the shape of a small quantity of electricity falling through a great difference of potential, and for other purposes a great quantity of electricity falling through a small difference of potential. When electricity falls through a difference of potential, this difference is called an electro-motive force. It would take me too long to tell you why we use two terms to express what seems to be the same thing; but briefly, the term "difference of potential" is analogous with "difference of pressure" or "head" of water, howsoever produced; whereas electro-motive force is analogous with the difference of pressure before and behind a slowly moving piston of the pump employed by an unfortunate miller to produce his water supply.

The first object of my paper is to show you that electricians have very definite ideas on the subjects they are working at; that the measurements, on which their work depends, have exact meanings, and that there is hardly any problem in adding to man's powers which you can set before them to solve which they may not hope to do with more or less costly apparatus. Everybody knows that the civil engineer is still very far from having reached the limiting lengths or sizes to which large bridges and other structures may be built, at a greater or less cost. Everybody is competent to form a roughly correct judgment in such matters, because everybody has more or less correct notions about sizes, weight, and strength of materials. And in the same way that you may be able to guess of what the electrician may do in the future, it is necessary that you get fairly correct ideas of electrical magnitudes; and the curious fact is, that, seeing how simple it is to arrive at these correct ideas, so few people possess them. On the wall-sheets II and III, I have given such help as can be given visibly in this matter; but time will not allow of my entering into such explanatory details as I should desire.

WALL-SHEET II.—ELECTRICAL MAGNITUDES.
(SOME RATHER APPROXIMATE.)

Resistance of

One yard of copper wire, one-eighth of an inch diameter................	0.002 ohm

One mile ordinary iron telegraph wire.........	10 to 20 ohms
Some of our selenium cells.	40 to 1,000,000
A good telegraph insulator.	4,000,000,000,000

Electromotive force of	Volts.
A pair of copper-iron junctions at a difference of temperature of 1° Fahr........=	0.000,01
Contact of zinc and copper...=	0.75
One Daniell's cell...........=	1.1
Mr. Latimer Clark's standard cell.........................=	1.45
One of Dr. De la Rue's batteries......................=	11,000

Lightning flashes probably many millions of volts.

Current measured by us in some experiments:

Using electrometer......=almost infinitely small currents.

	Weber.
Using delicate galvanometer..............	=0.000,000,000,040
Current received from Atlantic cable, when 25 words per minute are being sent.............	=0,000,001
Current in ordinary land telegraph lines...	=0.003
Current from dynamo machine....	=5 to 100 Webers

In any circuit, *current* in webers................=*electromotive force* in volts ÷ *resistance* in ohms.

Wall-sheet III.—Rate of Production of Heat, calculated in the shape of Horse Power.

In the whole of a circuit=*current* in webers × *electromotive force* in volts ÷ 746.

In any part of circuit = *current* in webers × *difference of potential* at the two ends of the part of the circuit in question ÷ 746.

Or, = square of current in webers × resistance of the part in ohms ÷ 746.

If there are a number of generators of electricity in a circuit, whose electromotive forces in volts are—E_1, E_2, &c., and if there are also opposing electro-motive forces, F_1, F_2, &c., volts, and if C is the current in webers, R the whole resistance of the circuit in ohms, P the total horse power taken in at the generators, Q the total horse power converted into some other form of energy and given out at the places where there are opposing electromotive forces, H the total horse power wasted in heat, because of resistance, then:

$$C=\frac{(E_1+E_2+\&c.)-(F_1+F_2+\&c.)}{R}$$

$$P=\frac{C}{746}(E_1+E_2+\&c.);\ Q=\frac{C}{746}(F_1+F_2+\&c.);$$

$$H=\frac{{}^2CR}{746}.$$

The lifting power of an electro magnet of given volume is proportional to the heat generated against resistance in the wire of the magnet.

The future of many electrical appliances depends on how general is the public comprehension of the lessons taught by these wall sheets. If a few capitalists in London would only spend a day or two in learning thoroughly what they mean, I am quite sure that electrical appliances of a very distant future would date from a few months hence.

It is not necessary for me to tell you now that electrical energy may be produced. Nor need I waste time in speaking of how it may be transmitted to a distance by means of insulated metal wires. A more important fact is that, when electricity is flowing in a wire, I can transform part of its energy into other shapes. For instance, here is an iron wire of 2 ohms resistance. Suppose this to be in a cold room, and I turn on the electricity tap. (An electric machine, driven outside by a gas engine, is here my source of energy.) This wire is now getting a supply of electrical energy, and is converting it into heat. Mr. Andrews tells me that there is now a current of 20 webers flowing through the wire, and hence the wire is giving out more than one horse power in the shape of heat. Some of you may have thought that very little heat can be given out by such a wire; but these are the exact figures, and you can all see that they represent a pretty large supply. When the current has been flowing for a short time, the neighborhood of this wire will be found unpleasantly warm, and I can assure you that the use of this instrument for certain measuring purposes is very disagreeable in the summer time. It is hardly necessary to say that a wire, through which a current is flowing, may be made to give out its heat for a great variety of purposes. The temperature may be pretty much what we please. Thus, I turn the tap, and this wire gives off very intense heat. (Experiment shown.)

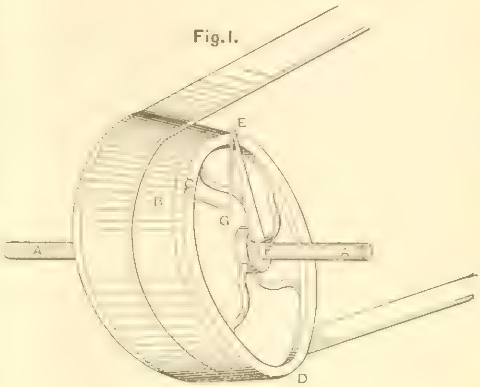
I had asked my friend, Mr. Andrews, to boil water for you by means of a hot spiral wire; but he has given us something of his own which is very much better. You see that I turn this tap, and so pass this current among all these little bits of carbon; first we have bright spots of light here and there stealing from point to point; then these lights fix themselves in definite places, and

round them the carbon gets red hot, until we get in two minutes the most perfect form of fire for heating a room or boiling a kettle that I have ever seen. I have in vain tried to get Mr. Andrews to exhibit before you to-night his exquisitely simple plate electric light. I have watched it burning, and knew that it has a future before it, if it were only from the fact that it burns steadily for a whole week with a powerful arc light without renewal of the carbons, and yet these carbons might be put in one's pocket, and the lamp thrown about anyhow, without risk of anything getting out of order. The excessive caution of the inventor prevents my showing you this simple little lamp. My own lamp is here before you, but beyond telling you that it is very simple, and that only one magnet is employed in the regulation and separation work, I may not detain you. I now turn another tap, and the strip, through which the current passes, becomes white hot, and we call it, vaguely, an electric light. (Experiment shown.) This is the incandescent light which has been proposed for use in ordinary houses. It is, confessedly, not econominal, but it is very convenient for chamber use. I now turn another tap, and you see a powerful Serrin lamp, which I mean to leave burning. You know now that we can convert electrical energy into heat and light; but the question is, how much of a result do we get for the power expended?

Professor Ayrton and his students measure at Cowper street, 1st, how much gas is being used by his gas engine; 2d, how much horse power is being actually given to his electric machine; 3d, how much current is produced through external circuits by his machine; 4th, the resistance of these circuits. He can now calculate exactly how much horse power is expended in any part of these circuits, and also how much light is actually given out by an electric lamp.

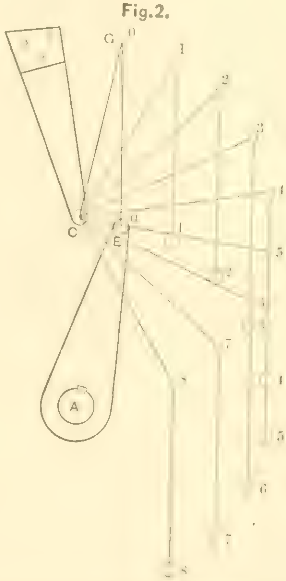
I must now try to give you an idea as to how these measurements are made. The very elegant dynamometer employed by our Chairman to measure the power which is being transmitted to a machine, I am not at liberty to describe. The plan devised by Professor Ayrton and myself is capable of being applied at very small cost to existing shafting in factories, so that the power given to any shaft may be known. A is a shaft which is to receive power. B is a loose pulley driven by a belt. C D is a wheel whose

Fig. I.



rim is fixed to the rim of B; its crooked arms are made of flexible steel, its boss being keyed to the shaft. Evidently B can no longer be called a loose pulley, if it turns it must cause the shaft to turn, but the turning moment is accurately represented by a certain amount of yielding of the steel arms of C D. If this yielding is known, and also the speed, the horse power transmitted is also known. For, so far, we copy the principle of General Morin. But instead of

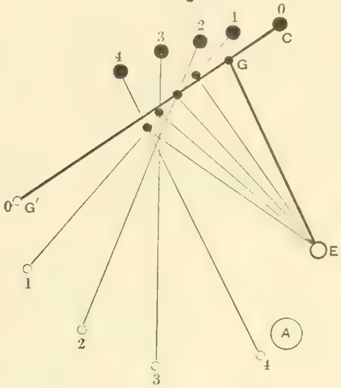
Fig. 2.



Another arrangement, giving greater range.

using his elaborate system of measurement, we simply convert the tangential strain into a radial motion which is visible. This may be done in various ways, of which the following is the most simple. A stiff arm, EA, is fixed to the shaft at A; at E and at a point C of the wheel, the ends of two light links are pivoted, which are hinged together at G, where there is a bright bead. Evidently,

Fig 3.



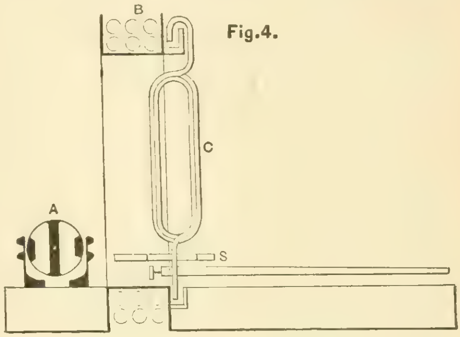
When tangential strain is small, this method of range is used.

if the distance CE becomes large, because much power is being transmitted, the bead G moves out from the center, and therefore the circle of light described by it has a greater radius. The arrangement shown in Fig. 3 is sometimes more convenient.

We measure the distance of the bead from the axis by means of a scale supported level with the shaft. Other dynamometers, which have till now been in use are shown in the diagrams. For measuring very strong currents, such as are used in electric lighting, Professor Ayrton and myself have devised this "dead-beat" galvanometer. Without going into a detailed description of the instrument, I may mention that it possesses the following great advantages. Not only can the strength of any current be read off at once in webers, but the user can at any moment test his own instrument, or graduate it, as it is technically called, by employing only the weak current produced by a single Daniell's cell. This result is arrived at by the device of causing the weak current to circulate 60 times round the magnets, while the strong current only goes round six times; a special form of commutating arrangement enabling the very same wires in the galvanometer to serve for both strong and weak currents; hence, comparisons can be made, not merely approximately, but with absolute accuracy, even if the wires are wound on the galvanometer quite carelessly.

The instrument shown in this diagram may be graduated in the same manner, as it is also provided with the same kind of commutator. We call it an arc-horse-power measurer, because its deflections

Fig.4.

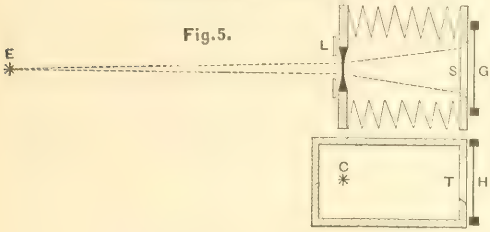


B, fixed coiled cable of ten strands, which may be used in "parallel arc" or in "series," by means of the commutator, A.
C, moveable coil.
S, spiral spring.

are proportional to the product of difference of potential established in an electric light, into current flowing through the arc, or incandescent carbon, and hence these deflections (see wall sheet II., p. 91) show at a glance the horse power given out at that place. The electro-dynamometers of Dr. Siemens and of Mr. Andrews are here before you, and may be used during the reading of the paper to measure currents. Mr. Andrews simply uses a steelyard to balance the attraction between two coils, when the current flows in them, when they are at a fixed distance asunder, and he, therefore, like Dr. Siemens, measures the mean square of the current flowing. These instruments have the disadvantage that an ordinary pair of scales has in comparison with a spring balance, viz., that a sudden temporary change in the thing weighed cannot be measured; but they have the advantage of great accuracy in the measurement of a constant effect.

To measure the light itself in standard candles, the students in the course of electric lighting, at Cowper street, employ our photometer (Fig. 5), of which three specimens are before you, and there is an enlarged drawing on the wall. The principle of old methods of measurement of strong lights was to weaken the intensity of illumination of a screen by taking the screen far enough away. Only in this way could the illumination of the screen by the electric light be made equal to the illumination of a similar screen by a standard candle. Our plan of weakening the light from an electric lamp is not by going forty or eighty feet away from it—for people who deal with electric lamps do not often possess a large enough chamber with blackened walls—but by letting, instead, the light pass through a concave lens. The principle is then exceedingly simple. Mr. Wormell has been making a few measurements whilst I have been talking, and I see that this electric light seen through green glass has varied from 2.214 to 2.136 candles in the last three minutes. Sir William Thomson suggested to us to make two measurements, one through green and the other through red glass, for reasons which must be obvious. Any one who may wish it will have an opportunity of measuring the power of an electric light for himself after the lecture.

DISPERSION PHOTOMETER.



E, electric light.
C, standard candle.
S and T, screens of tissue paper.
G, H, plates of green or red glass.

$E \propto \frac{EL^2 . LS^2}{CT^2}$

From all this you will see that perfect methods exist for measuring the power which is being given out as heat or light in any part of a circuit, as well as the power given to the electrical machine. In fact, we have a perfect measure of what is called the efficiency of our arrangement.

It is hardly necessary to tell you that every house and every street may be lighted electrically. Into the proof that, in the future, arc lamps of thousands of candle power at elevations proportional to the square roots of their powers, will be used for large spaces, and that incandescent lamps of only hundreds of candle power are suitable only for private houses; into a consideration of these statements I shall not enter, because Professor Adams is dealing with the question in his Cantor lectures. You all, in one way or another, feel that electric lighting is a foregone conclusion. But, perhaps, you were not aware that buildings may be heated by electricity. The neighbors of this iron wire will say that it gives out a considerable quantity of heat, but whether the heating may be performed economically will depend on the story told us by the measurements which have been made. Now let me turn my tap again. I let my current pass through this insignificant little dynamo machine, and you observe that it is in motion; not only is it in motion itself, but it is driving this lathe. A machine is receiving mechanical energy outside, it converts this into electrical energy, which is conveyed by wires into the room and to the machine before you, where it is converted into mechanical energy again. I think I shall never forget the astonishment of a workman in Sheffield, who had put up a saw bench for use at Professor Ayrton's lecture, and who was about to rehearse his part. He looked at the motionless saw, he had his hand on the wood, he saw there was a belt from a little mite of an electric machine, two wires dangled from the ceiling to the machine, and that was all. What notions of being played with came into his mind I do not know, but when, at the distant place, a water engine was started to drive the distant machine, when the saw set off nearly at its full speed, and the two dangling wires were evidently the only methods of communication, this thoughtful workman's face expressed in full perfection the absence of all his reasoning powers. I do not wish you to lose your reasoning powers, but it is necessary that you should get thoroughly impressed with the notion that the

power to drive this lathe is actually being transmitted through these limp and motionless wires.

I should like to be able to hold that machine motionless, and to prove to you that the current flowing through the wires is immediately diminished when the machine begins to move. In fact, I want to show you that this machine produces an electromotive force, which is in opposition to that of the distant machine. You see that we are just able to hold it, and now I am informed that the current flowing is 19.5 webers, whereas if we let it run, and drive the lathe and the sewing machine and this fan, you will find that the current is diminished. It is 11.2 webers, or about half what it was before. It is not necessary to give you further examples of this transmission of power by electricity, but on account of the evident importance of the matter to the health of the community, I will give you one more, and I turn the tap, and you all see that the insignificant little machine is driving a ventilator. This ventilator might be used in a chimney in the summer time when fires are not in use, or in any suitable outlet from rooms; and pray remember that mechanical ventilation is ever so much more efficient than what is called natural ventilation, in which advantage is taken of the lightness of warm gases.

Now, what do these examples show you? They show that if I have a steam engine in my back yard, I can transmit power to various machines in my house, and if you measured the power given to these machines, you would find it to be less than half of what the engine driving the outside electrical machine gives to it. Further, when we wanted to think of the heating of buildings and the boiling of water, it was all very well to speak of the conversion of electrical energy into heat, but now we find that not only do the two electrical machines get heated and give out heat, but heat is given out by our connecting wires. We have then to consider our most important question. Electrical energy can be transmitted to a distance, and even to many thousands of miles, but can it be transformed at the distant place into mechanical or any other required form of energy, nearly equal in amount to what was supplied? Unfortunately, I must say that hitherto the practical answer made to us by existing machines is, "No;" there is always a great waste due to the heat spoken of above. But, fortunately, we have faith in the measurements of which I have already spoken, in the facts given us by Joule's experiments, and formulated in ways we can understand. And these facts tell us that in electric machines of the future, and in their connecting wires, there will be little heating, and therefore little loss. We shall, I believe, at no distant date, have great central stations, possibly situated at the bottom of coal pits, where enormous steam engines will drive enormous electric machines. We shall have wires laid along every street, tapped into every house, as gas pipes are at present; we shall have the quantity of electricity used in each house registered, as gas is at present, and it will be passed through little electric machines to drive machinery, to produce ventilation, to replace stoves and fires, to work apple parers, and mangles, and barbers' brushes, among other things, as well as to give everybody an electric light.

Probably you think it very strange that I should show you the ineffiency of electric transmission of energy, and then make this very bold assertion. Well, the fact is, that the ordinary electrical machines in use have not been constructed with a view to economy. They have been constructed to show that brilliant lights and considerable power may be produced from small machines. They have, at a comparatively small cost, attracted attention to the fact that electricity is an important agency. In so far they have done well; but on the other hand, they gave rise to the well-known assumption that 50 per cent. of the mechanical power given to the generator, was the maximum amount which could be taken from the motor. The true solution of the problem of transmission of power was, I believe, first given by Professor Ayrton in his British Association lecture at Sheffield. It had been supposed that to transmit the power of Niagara Falls to New York, a copper cable of enormous thickness would be needed. Mr. Ayrton showed that the whole power might be transmitted by a fine copper wire, if it could only be sufficiently well insulated. He

also showed that, instead of a limiting efficiency of 50 per cent., the one thing preventing our receiving the whole of our power was the mechanical friction which occurs in the machines. He showed, in fact, how to get rid of electrical friction. I will briefly give you our reasons. A machine at Niagara receives mechanical power, and generates electricity. Call this the generator, and remember that wall sheet III teaches us that the mechanical power is proportional to the electromotive force produced in the generator, multiplied into the current which is actually allowed to flow. Let there be wires to another electric machine in New York, which will receive electricity, and give out mechanical work, as this machine does here. Now, I showed you a little while ago, that this machine, which may be called the motor, produces a back electromotive force, and the mechanical power given out is proportional to the back electromotive force, multiplied into the current. The current, which is, of course, the same at Niagara as at New York, is proportional to the difference of the two electromotive forces, and the heat wasted is proportional to the square of the current. You see, then, from wall sheet III, that we have the simple proportion—power utilized is to power wasted, as the back electromotive force of the motor is to the difference between electromotive forces of generator and motor. This reason is very shortly and yet very exactly given in wall sheet IV.

Let electromotive force of generator be E; of motor F. Let total resistance of circuit be R. Then if we call P the horse power received by the generator at Niagara. Q the horse power given out by motor at New York, that is, utilized. H, the horse power wasted as heat in machines and circuit. C, the current flowing through the circuit.

$$C=\frac{E-F}{R}$$

$$P=\frac{E(E-F)}{746R}$$

$$Q=\frac{F(E-F)}{746R}$$

$$H=\frac{(E-F)^2}{746R}$$

$$Q:H::F:E-F$$

To put it more shortly still, the power wasted is proportional to the square of the current flowing, whereas the power utilized is proportional to the current, and also to the electromotive force of the motor. The greater, then, we make the electro-motive forces, the less is the loss of power in the whole operation. Perhaps you will see this better from the water analogy. A small quantity of water flowing through a water main, may convey a large amount of energy, if it only has sufficient head. The frictional loss of power is independent of the head, but depends very much on the quantity of water. In the model before you is the water analogy. (Experiment shown.) A is a reservoir, kept filled with water by a steam pump, which draws the water from the sea level, K K. Water flows from reservoir A to distant reservoir, B, where it drives a turbine giving out work due to its head, B K. The current from A to B, through the communcating pipe, is the same always, so long as A and B are at the same difference of level, and therefore the frictional loss of energy is always the same, whereas the work utilized from B, by driving the turbine, increases proportionally to the height of B above sea level.

The result, then, to which the above laws led Professor Ayrton and myself was that for the future development of the transmission and distribution of electric energy it will be necessary to use electric machines of great electromotive force. Indeed, so important must this principle become, that we believe there is a future in this direction for the employment of plate electrical machines, such as that of Holtz. Now the electromotive force of an electric machine may be increased in three ways: 1. By increased speed, as you easily see when I turn this magneto machine more rapidly. 2. By increased strength of magnetic fields. 3. By increasing the length of wire on the moving armature. Of these methods the first is most important. Now, if iron is used in the armature, since it is magnetized and demagnetized very rapidly its coercitive force prevents this magnetization and demagnetization being as complete at the high speeds I contemplated, as it is at the ordinary speeds of the present

day. I say this in spite of the fact shown by some unpublished experiments of ours, which imply that the magnetization and demagnetization of a bundle of fine soft iron wires are as complete when effected sixty times per second as when effected once per second. Besides this, a very considerable quantity of heat is developed in such rapid magnetization and demagnetization as does occur. The electric machines of the future will, I am convinced, be without iron in their movable parts. High speeds necessitate careful construction and the balancing of moving parts, and great attention being given to rubbing surfaces. By rubbing surfaces, I do not merely mean the bearings of the machine, but the commutator, which is rubbed by the collecting brushes. Much of the waste of energy by mere mechanical friction which occurs in electric machines occurs at the brushes; but, hitherto, other waste has been so great that this might be neglected as unimportant. But it is very important in the machines of the future. The loss of energy by friction is proportional to the number of revolutions per minute, and to the diameter of the rubbing surface. I have given considerable thought to the reduction of this friction, and have arrived at a form of commutator shown at A in the diagram (Fig. 4), which largely dininishes the loss. The parts of the commutator must be firmly fixed, but they must also be well insulated from one another, therefore they must be separated by some rigid insulator, such as ebonite, at the places where they are screwed up; hence, they are necessarily far apart at these places. If they are rubbed at these places, however, there will be a great loss of power in friction, and hence they ought to be bent in towards the axis of rotation, where they may be insulated from one another by narrow air spaces, and where they may be rubbed by the brushes, with only a small waste of energy. This plan I have proved to be quite feasible. In the larger machines of the future, its importance will become much more manifest that it can be in existing machines. This frictional principle is illustrated by the model before you. Here are two surfaces, making the same number of revolutions per minute. If the same amount of rubbing occurs, you observe that when I rub the surface of larger diameter, there is great loss of energy, and the motion is stopped; whereas, when I rub the surface of smaller diameter, there is only a small loss of energy, and the motion is not stopped. (Experiment shown.)

This necessity for a great velocity of moving coils past fixed magnets, necessitates increase of size of the armature, because for a given velocity the centrifugal force tending to burst the revolving armature is inversely proportional to the radius. For instance, here are two light wheels, made in exactly the same way. You can examine their construction at the end of the meeting. They are rotated at a different number of revolutions per minute, so that the actual velocities of their rims shall be the same. You observe that the rim of the smaller bursts in pieces, and the larger is unhurt.

There is another important reason for increased size, namely, that of similar dynamo machines, one twice as large as the other: the larger is capable of giving out eight or more times as much energy for the same number of revolutions per minute. It would delay me too much to go into this question of size fully; but if it be remembered that the electromotive force of each moving coil is proportional to its area, then, without taking into account increase of strength of magnetic field, which certainly occurs with larger machines, we get eight times as much effect for double the size. Electric machines of the future will, then, probably, be of great size, moving with exceedingly great velocity.

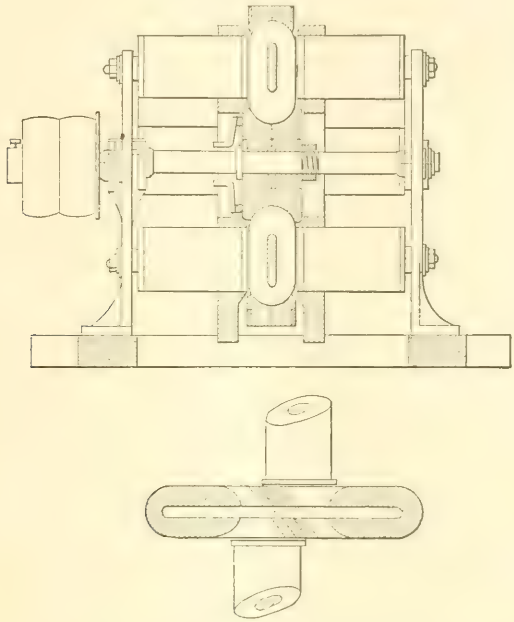
The third method of increasing the electromotive force by having greater lengths of wire in the armature is always available, but inasmuch as every increase so produced causes a proportional increase in the resistance of the circuit, and therefore a waste by heating, this method is not quite so economical as the increase-of-speed method.

It is to be remembered that the lifting power produced in an electro-magnet of given size is simply proportional to the heat produced in the wire on the magnet, and if it is our object to diminish this heat, we must discard all idea of working the magnets of electric machines by their own currents. In fact,

the function of dynamo machines, like these I have been using, will, in the future, be to feed the magnets of larger machines, or else they will give place altogether to magneto-electric machines. I have now given you, very briefly, some of the reasons which have occurred to us for believing that very large continuous current machines, with separate exciters, or, perhaps, even magneto-electric machines driven very fast by steam engines, will have an important place in the much electrical energy and striking light effects may be produced by a small and portable machine. They have drawn the attention of capitalists to electric lighting and electric railways, and in this way have done great service. Calculations of possible economy in the future, deduced from their action merely, must, however, be quite misleading. But if the facts given in this wall sheet are correct—and, fortunately, there can be no doubt of their correctness—the practi-

PERRY'S DYNAMO MACHINE.

Fig.6.



future transmission of energy by electrical methods. With such machines it would be possible to heat, light, and ventilate all the houses in New York, and to give to large and small workshops the power required to drive their machinery by means of an ordinary telegraph wire (but with some exceptionally good method of insulation), transmitting energy from as great a distance as the Falls of Niagara.

When I speak of what will be done in the future, in this direction, I can speak with perfect certainty. It is useless to tell us that existing machines are not economical. As I have already said, existing machines have been made with a very different purpose; to show that cal transmission of all kinds of power to all distances; the supply of large and small quantities of light and machine power to all parts of a city like London from a single center, and a consequent return to that old state in which in many trades it was possible to dispense with the congregation of great numbers of men in large manufactories, is a thing to be looked forward to with perfect certainty. I need hardly tell you that heating houses by electricity will completely get rid of the smoke nuisance. I have been dealing with general principles, and electricians will take various plans to carry out the idea put before you. In my own machine, exhibited here, and also drawn upon this diagram (Fig. 6), I

have endeavored to carry them out in my own way. This is the largest machine which I could induce my kind friends, the firm of Messrs. Clark and Muirhead, to construct for me. I would, were money enough available, apply the principle to coils wound obliquely on the thin rim of a great fly-wheel of a large steam engine, fixing magnets obliquely to one another on both sides of the rim.

I have so much pecuniary interest in the future of this machine that it would take from the impersonal character of the lecture if I brought it before you too prominently. Its performance may be examined into at the manufactory. If time allowed, I would rather dwell on the enormous social phenomena which are preparing to develop themselves. England is a very rich country. She can afford, even through her Government which dispenses only a small portion of her wealth, to carry out great enterprises at the ends of the earth. By her canals and roads, and then by her railways, she has made herself comfortable, and has added to her wealth. Adding to her wealth is an accidental effect, perhaps, but adding to the happiness and health of the poorest people in this cradle of the Anglo-Saxon race is certainly the most important work to be effected by the wealth of England. To do this, through the agency of electricity, will not prove a bad financial investment.

Leaving this very large subject, let me speak of a few of the applications of the above principles which have a future before them. The development of the telephone and of telephone exchanges, until every person in London can speak directly with every other Londoner, and, indeed, with every other person in the country; this, as you all know, is quite a settled matter, although, no doubt, there are little difficulties still to be surmounted. At one end of a telephone wire there is a generator, a magneto-electro machine, which receives sound energy, and gives out electricity. At the other end there is a receiver, or motor, another such machine, which receives electric energy and gives out sound. We have, in fact, a simple example, and one of the most economical examples I know of, for the transmission of power by means of electricity. Quick speeds caused by vibrations of many hundred times per second, and strong magnetic fields, have produced this wonderful economy, which enables men in Paris to speak with members of their family in Marseilles. Again, the subject of electric railways is a part of the much larger subject which I have already dealt with. I suppose you all know the general principle of electric railways as hitherto constructed. Only that we like to observe large effects produced, the model which is now working before you would give as clear ideas of future constructions of this kind as the Berlin railway, or the one to be exhibited at Paris. [In this experiment a circular railway was worked from a magneto-electric machine driven by hand.] A generator of electricity is driven by a large stationary engine, somewhere in the neighborhood of the railway. A motor on a carriage receives electric energy by the conducting rails, and converts this into mechanical work to drive the carriage. Even the small experiments of Dr. Siemens show that there can be no doubt that the introduction of electric railways everywhere is merely a question of capital, and the sacrifice of much existing plant. This kind of proof was very much needed by capitalists. But the electrician sees much further; he sees better insulation for the conductor, and application of the above principles to hundreds of miles of rail instead of a thousand yards; he sees, in fact, that the larger the experiment, the greater must be its success. He looks forward to the absence of a vitiated atmosphere in our underground railways. He sees that the weight of rails (for there will be no heavy locomotive in the future; each carriage will have its own driving and braking machinery), and the cost of bridges, and wear and tear of permanent way, may become less than one-quarter of what they are at present; he sees, in fact, all the advantages that will arise, when, instead of making a heavy steam-engine travel backwards and forwards with carriages, the carriages alone travel, and the steam-engine is not near the railway at all. In that case, also, all the energy at present wasted in stopping a train, will simply be given back to the generator.

I have mentioned electric lighting, and telephones, and railways, because I know

that many of you must have expected to hear of them, but I mainly wish you to consider these appliances as examples simply of the transmission of power by electrical means. In the same way I might refer to a countless number of other appliances, giving you a mere catalogue of them; but, from the ordinary house-bell to the complicated arrangement by which my brother regulates the weirs on a river to prevent floods; from the time-regulating luxury of certain clockmakers, to the quadruplex telegraphy of Muirhead and Winter, they are simply methods of transmitting energy by electricity, and as such, their economical devolopment depends on the recognition of the above principles. Take, for example, the case of ordinary telegraphy. There can be no doubt that it is absurd to fill large houses with tens of thousands of voltaic cells to work telegraph lines. But it is not sufficient for the Post-office authorities to feel the annoyance, and merely try to replace batteries with such a machine as you see before you—a machine of but one *ohm* resistance, while every mile of telegraph wire may have twenty ohms resistance. I am sure that everybody belonging to the telegraph department will be satisfied with a change that gives them one dynamo machine for all those thousands of sloppy voltaic cells; and there is no longer any excuse for further delay, since Mr. Schwendler has been perfectly successful in working long telegraph lines in India in this very manner.

When we think of electricity as an agent by means of which energy may be transferred and altered, it is natural to ask if, by means of it, energy can be stored up. If we could obtain an efficient method of storing energy, the result would be of very great importance in a variety of ways. Thus, if all the work obtainable from the tide filling and emptying great shallow basins, could be stored up, so that it might be given out steadily, and only at our pleasure; if all the work obtainable from wind-power, which is constantly varying, could likewise be stored up, so as to be readily available, a long-standing difficulty would be got rid of, which has hitherto prevented the working out of large schemes for the utilization of these sources of natural power. And not only in these large cases, but in a countless number of other ways, is it important to possess means of storing energy. In the manufacture of gunpowder, and in many chemical operations, energy is stored up; but no such method can ever become economical. It has to be remembered, however, that electrical operations may be made as economical as we please; and however insignificant the method may appear to be just now, it may assume great importance in the future, from the fact that, with the exception of the lifting of heavy bodies to higher levels, an electrical method of storage may be made more economical than any other. Now when I charge this Leyden jar (experiment shown) you know that I store electrical energy, and I can use my stored energy at any future time if the insulation of my jar is good. Thus I have converted a small store into heat and light. (Experiment shown.) Again, I can use this store at any time to give itself out at a distant place. This is a very small store. But now observe that my thermopile has been working for nearly an hour, and some time ago it had filled these two test tubes with oxygen and hydrogen. With these two gases I can produce, as you all know, a most intense heat. You all know that this lime light is produced simply through my having such a store in these iron bottles which you see before you. Remember that these gases might be kept stored up for as long as we like, and that if a windmill worked a magneto-electric machine it could produce such a store working now fast, now slow. Well, but I can take this store and convert it again into electricity with very little loss. You will see that it can produce an electric current if we have two similar metal plates in the positions you see them in, and if I connect these metal plates through the galvanometer (experiment shown), you have there evidence of a current, this deflection of the needle of the galvanometer. This current will continue to flow, and the electric energy will continue to be given out until all the store of gas disappears.

Instead of using that weak thermopile, suppose I had used this strong current produced by the outside engine, you see how much more rapidly my store is formed. (Experiment shown, in which

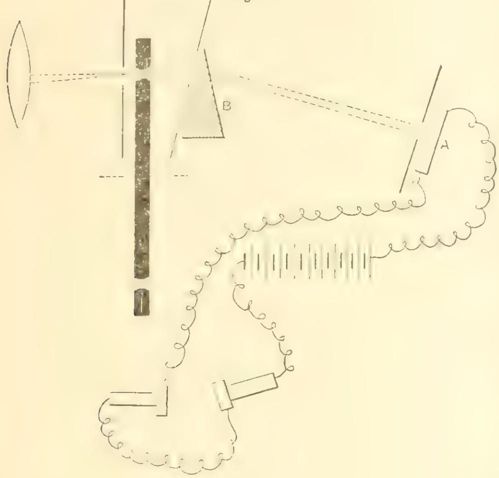
the gases rapidly formed were used to produce an oxy-hydrogen lime light.) I grant that the elaboration of this gas battery into a compact generator, sufficiently powerful to produce very large effects, is a problem of some expense for future workers; but give it to any electrician, and make it worth his while, and I believe that such a generator might be constructed in a very short time.

To introduce the next part of my subject, let me ask—Can anybody hear the sound by a puff of air as it passes through the hole in this cardboard disc? (Experiment made.) Nobody heard it, or the difference produced when the air was stopped by the cardboard. But suppose I repeat this operation several hundred times per second, you can all hear the powerful musical note given out. (Experiment.) You see, then, that the rapid recurrence of effects may be very sensible to us, although one such effect may not be sensible. In the same way, if light streamed through one of the holes in this brass disc into your eyes, it would not produce a very striking effect; whereas Professor Tyndall says that when such a disc as this was rotating so as to let the light falling on his eyes be very rapidly intermittent, he experienced the most extraordinary sensations. Again, if I very much alter the magnetic field in this telephone, by bringing a powerful magnet near it, with great care in listening I hear the faintest sigh, due to the diaphragm settling itself into a new position, its vibrations dying away as it does so; and if I brought a small magnet near, I should hear nothing. And yet the change of magnetism which produces the loud telephonic effects which we listen to is almost infinitely smaller. Why is this? It is due to the rapid recurrence of the effects. Now you are all aware of the importance of the telephone as a method of communication; I believe that a much greater importance is in store for it as a laboratory appliance.

Here is a selenium cell through which I can pass a current of electricity from this large battery, which also passes through these two telephones, which I can hold to my ears. When light falls on this selenium its electric resistance is diminished, and a stronger current passes. This is a property discovered by Mr. Willoughby Smith. Now I cannot hear in the telephone any effect produced by letting light suddenly fall on the selenium. The difference of current produced in the very case before you is only one two-thousandth of a weber. But if I rotate this brass disc so as to make the light fall with intermittence several hundreds of times in a second on the selenium, I can distinctly hear a musical sound. This is what Professor Bell has been exhibiting lately, and it constitutes the principle of the photophone. Now to give you an idea of the new ground which the use of the principle of recurrence is opening up in laboratory work, let me speak of an experiment which is now in progress. Professor Bell spoke in his lecture of having tried to stop the intermittent rays of light of this instrument by a sheet of ebonite like this, but he found that there was still a very faint sound from the telephones. Well, it occurred to Professor Ayrton and myself that if ebonite is transparent to some kind of invisible radiation, then in all probability it is capable of refracting such invisible rays. So we obtained this ebonite lens, and two prisms, and tried. We thought the lens would bring the invisible rays to a focus, but as our lens was not mounted, so that we could move it parallel to itself, and as the rays are, of course, quite invisible, so that our eyes cannot help us to focus the ebonite lens, we did not succeed in this very delicate experiment, which the following experiment, however, shows, must ultimately be successful. Next we placed the cell at A in this diagram (Fig. 7), and found that it gave out no sound, being beyond the range of the beam of intermittent light. We placed the prism in the position B, in which you see it, and, to our great satisfaction, a sound was heard. You must remember that this sound, and any sound obtained from light that had passed through ebonite, was exceedingly feeble. The person who listened was in another room, so as not to be in any way influenced by what he saw, and his preciseness in detecting sound was determined by another experimenter putting his hand in the beam of light and taking it away again. So that there could be no doubt as to the origin of the faint sounds heard. Well, the prism caused the light to bend round,

and now the question was as to how much bending it produced. We provided two pieces of zinc plate, with slits cut in them. You all understand, I hope, that the most advanced physicists regard a metal as a perfectly opaque body, even to invisible rays, so that rays can only pass through the slit in our zinc. Well, we placed the slit in the zinc within a short distance of the edge of the prism, and found a position in which the rays, passing through the slit, still reached the selenium. The sound was now very faint. Then we searched on the selenium

Fig.7.



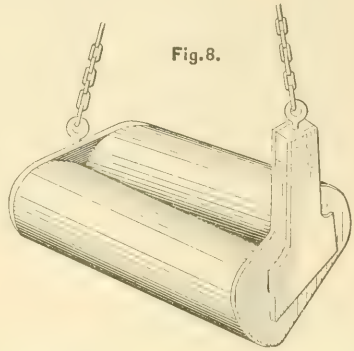
with the edge of our second piece of zinc, to find what region of the cell might be covered without destroying the sound. We found that region, and placed our second slit there. Rays passing through the first slit were now passing through the second slit. If either was changed in position, the sound died away instantaneously. Thus, there could be no doubt of the fact that ebonite refracted that invisible beam, about which nothing else is as yet known. If our slits had been very narrow we could have measured accurately the index of refraction, but with narrow slits the sounds were too faint to be heard in the center of London ; so all that we can say at present is, that ebonite certainly refracts light, and its index of refraction is, speaking quite roughly, 1.7. Now, it is somewhat curious that this was the rough measurement which we made. For Clerk Maxwell's theory, that light is propagated through space like an electro-magnetic disturbance, requires the square of the index of refraction, for light of very low refrangibility to be equal to the electric specific inductive capacity of the substance, and it has long been known that this electric constant for ebonite varies from 2.2 to 3 5 in different specimens. The square of 1.7 is 2.89. Thus, you see that this curious following out of our first idea has led to a further backing up of Clerk Maxwell's electro-magnetic theory of light. This and other investigations which we are now proceeding with, illustrate two important things, namely—the principle of recurrent effects in the use of the telephone, has opened up a new path into unexplored nature; and, secondly, the laboratory worker sees before him a hundred interesting phenomena, which ought to be investigated at once, and which he cannot take up unless he gets more apparatus, more money, and more observing eyes and working hands.

About two years ago, it struck Professor Ayrton and myself, when thinking how very faint musical sounds are heard distinctly from the telephone in spite of loud noises in the neighborhood, that there was an application of this principle of recurrent effects of far more practical importance than any other, namely, in the use of musical notes for coast warnings in thick weather.* You will say that fog bells and horns are an old story, and that they have not been particularly successful, but our scheme was of a somewhat different kind. In northern Japan, where fogs are the rule and not the exception, which they are in England, and where changing currents of more than six knots are common off many dangerous parts of the coasts, shipmasters are very much in the habit of using their steam whistles, listening for the echo from the steep coasts, and judging from the interval of elapsed time what is their distance from the coast, and what is their

* Since the reading of this paper, my attention has been drawn to a letter in the *Engineer*, of Jan. 28th, 1876, from Mr. H. T. Humphreys, who there suggests the use of submarine sirens as coast warnings. Since the idea struck Mr. Ayrton and myself, we have been wondering how it escaped attention so long. We now wonder why the lighthouse authorities have made no efforts in the last five years to carry Mr. Humphreys' idea into effect.

position. But they find that on many foggy days they can, and on other foggy days they cannot use this method, because they may hear no echo, although quite near the coast. Now, it seems to be forgotton by everybody that there is a medium of communication with a distant ship, namely, the water, which is not at all influenced by changes in the weather. At some twenty or thirty feet below the surface there is an almost perfect calm, although there may be large waves at the surface. Suppose a large water-siren like this (experiment shown) is working at as great a depth as is available, off a dangerons coast, the sound it gives out is transmitted so as to be heard at exceedingly great distances by an ear pressed against a strip of wood or metal dipping into the water. If the strip is connected with a much larger wooden or metallic surface in the water, the sound is heard much more distinctly. Now, the sides of a ship form a very large collecting surface, and at the distance of several miles from such a water siren as might be constructed, we feel quite sure that, above the noise of engines and flapping sails, above the far more troublesome noise of waves striking the ship's side, the musical note of the distant siren would be heard giving warning of a dangerous neighborhood. I have no time now to tell you of the small experiments we have made in this direction. This electric bell sounds only very faintly when in water, and yet we have been able to hear it at the distance of sixty feet along a trough of water in a place filled with the noise of much heavy machinery. We took this water siren to Hastings for a trial in ordinary boats, but the weather was too rough at the time for boats to go out; and, therefore, the experiment had to be postponed. We have constructed the arrangement shown full size in this diagram, in which currents of electricity are sent from a distance sufficiently rapidly intermittent through this electro magnet to give the natural period of vibration to this armature when in water (Fig. 8). Whether this will prove successful or not we do not know, but we feel sure that the idea is to be carried out electrically, the source of sound being a motor worked by a generator on the nearest coast. In considering this problem, you must remember that Messrs. Colladon and Sturm heard distinctly the sound of a bell struck under water at the distance of nearly nine miles, the sound being communicated by the water of Lake Geneva.

Fig.8.



An electro-magnet, with vibrating armature, giving out loud musical note.

Another application of the principle of recurrent effects, which may, indeed, be regarded as the earliest of such applications, is this multiple telegraph of Mr. Elisha Gray, which my friend Mr. Graham has been kind enough to put in working order, so that it may be worked from this table to the telephones hanging against that wall. About this telegraph, which allows a great number of messages to be sent through an ordinary telegraph wire at the same time, Sir William Thomson wrote to me in terms of high eulogium when he first examined it at Philadelphia. At present I believe that the quadruplex system is more favorably looked upon because it has succeeded better in practice, but I am inclined to think that in the distant future it may possibly have enormous development.

In this paper I wish I could bring in, as illustrations of the few great principles which are really the important factors in the future development of electrical appliances, the microphone and all the instruments which have been derived from it, but even to refer to them would take far too much time. I would end by speaking of two appliances which are of quite a different species, namely, Mr. Edward Bright's method of de-electrifying woolen yarn, and of a contrivance for seeing by electricity. In the manufacture, the woolen yarn becomes electrified by

friction, and has hitherto lost its electricity very slowly, requiring to be stored for many months in damp cellars before it got rid of its electricity. Until lately, nobody seems to have suspected that it was electricity which caused the fibres to stick out on all sides of the yarn instead of staying in an interlaced condition. It was found to occur most in dry weather, and was vaguely put down by Englishmen to "the weather." So very annoying was this in a dry climate, that although Bradford men and Bradford machines were taken to America, only two months in the year could really be devoted to the manufacture. Now, we have here some wool staple in the air which is being electrified by this plate machine. You see how the fibers repel one another and remain in this state. You observe, however, that these other fibers we try vainly to electrify because they are in a partial vacuum, and electricity escapes from them as rapidly as it is formed. I will allow air to enter this air-pump receiver, and now, when the machine is worked, you see (experiment shown) that these fibers retain their electricity. The principle that a partial vacuum is very conductive has long been known to electricians, but the remarkable saving in woolen manufacture, effected by applying a knowledge of the principle, was left for Mr. Bright. Mr. Bright's plan of operations is to have chambers where partial vacua may be produced. He wheels large trucks of electrified bobbins of yarn into these chambers, and takes them out very soon, unelectrified, thus performing, in a few minutes, an operation that used to be badly performed, in a costly manner, in half a year. Can we doubt that, when boys obtain, in all elementary schools, a little knowledge of electricity, there will be rapid additions to the number of electrical appliances?

And now let me come to the last of the developments of electrical appliances, still perhaps somewhat in the future. A picture in *Punch* of an aged couple at home seeing on their drawing-room wall an image of their children playing lawn-tennis out in India, and of their conversing with some of them by telephone, first led Mr. Ayrton and myself to think of this matter. We showed that it was feasible, in a letter to *Nature*, and in the *Times* about a year ago. The feasibility of the method described by us was doubted, and we therefore proved it at a meeting of the Physical Society four weeks ago. I mean to put it before you in a sligujly different form. Suppose that place is York, and this is London. I have a little selenium cell at York on a certain part of this picture, and at London I can throw at a corresponding place on this screen a square of light; and suppose that the illumination of this square is governed by a little movable shutter which is attached to the needle of a galvanometer. Now when light falls on the selenium at York, an immediate change occurs in it, so that more current flows to London, and this opens the shutter. The London square is then bright, when the York selenium is in bright illumination. When the York selenium is in shade or darkness, you see that the London square is in corresponding shade or darkness. (Experiment shown.) Now suppose that we form an image of this girl with her skipping rope at York, and cause a selenium cell at York to travel across her image, and suppose that this mirror at London moves so as to cause the illumination which passes the shutter to traverse this London screen isochronously—an operation performed in several telegraph instruments. Then whenever this cell reaches a dark, or shady, or bright place in the image at York, there will be darkness, or shade, or brightness at the corresponding place in London. And now suppose that this motion is effected rapidly enough, you are all aware that if the shutter is only quick enough in its answering motions, the image of the part of the screen at York traversed by the cell will be faithfully reproduced, and will remain on the retina at London as a distinct picture in black, and gray, and white, just like a photograph. With then, perhaps, forty such cells as this, all moving in the way spoken of, or a smaller number rotating on a radial arm, it would actually be possible to show at London, not merely an image of a girl at York, but an image of a girl skipping. You will, perhaps, understand better this principle from the model. Here is a path of black and white spaces at York, over which this selenium cell is made to travel. We have continued the images to the paper above, simply to let you know when the cell is in the image of a

dark place, and when it is in the image of a bright place, so that you may be able to say whether there is a faithful reproduction at London. These two frames are really tied together by this long string to make them move isochronously. In practice, I need hardly say that this function will be performed in another but quite as feasible a manner.

The cell at York is in a black part of

I had hoped to be able to present to you the scheme which Mr. Shelford Bidwell has proved to be feasible, of reproducing in shaded lines on paper, by electro-chemical decomposition, a picture of a distant stationary object. I understand, however, that Mr. Bidwell has been asked to read a paper here, when he will exhibit the model he has made.

Fig. 9.

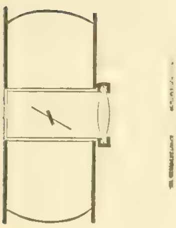
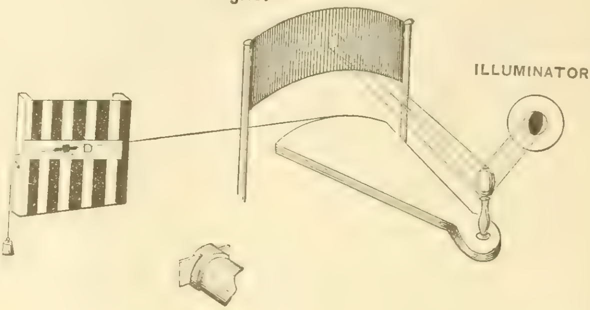


Fig. 10.



the picture; you observe no light on that part of the screen in London. The cell at York is in a bright part of the picture; the corresponding part of the screen at London is bright. And so we find that, as the cell goes successively through dark and bright places, so the corresponding parts of the screen at London are made dark and bright. (Experiment shown.) Our shutter is not yet sufficiently deadbeat for us to make this motion rapidly.

I had hoped to be able to show you to-night the development of this method, by using what we have called the Japanese-mirror principle. We have shown that the most minute effects on the backs of metal mirrors, effects quite invisible when examining the polished surface of the mirror, are very visible in the reflection of a divergent beam of light. Such effects, we believe, we can produce by electro-magnets arranged radially behind a circular mirror and rotating with it. This radial arrangement of magnets will move synchronously with a radial arrangement of corresponding cells. The principle, however, is exactly the same as that shown by this model, only we know that the change of curvature at a point in a mirror will obey changes of magnetic effects more rapidly than this shutter does.

In my paper read here a year ago it was the importance of giving artisans facilities for obtaining practically exact knowledge in science that I especially laid stress on. To-night I have desired, first, to show what benefits our country would receive from an exact knowledge of electrical magnitudes, and of the fundamental laws of electricity being more widely disseminated, and, second, how the principle of recurrent effects may be employed to assist our senses.

At a recent meeting of the California Academy of Sciences, Dr. H. Gibbons said that since he put petroleum on the trees in his garden they have grown better and faster than ever before, and given better roses than before. The petroleum seems to kill the scale insect. The handsomest rose he exhibited was from a bush which looked nearly dead a short time before. The petroleum was mixed with castor oil. It is applied sparingly, and great care taken that it does not run down the roots. Perhaps in a crude state the petroleum would be bad, even on the stalks; but mixed with the castor oil it appears to be advantageous to the plant.

EQUILIBRIUM OF PULVERULENT BODIES.

By PROFESSOR J. BOUSSIN, Esq.

From Foreign Abstracts of Institution of Civil Engineers.

Pulverulent bodies, such as sand or earth recently turned up, whose particles in sliding on one another experience no resistance except that arising from their mutual friction, are susceptible of many distinct modes of equilibrium.

The only one which has hitherto been studied is the limiting case when the mass is on the point of motion, and when the friction of the particles attains its maximum. Formulæ relating to this state were obtained as early as 1856 by Rankine, and subsequently by Levy and others.

But there is another kind of equilibrium equally important to consider, viz., that which is produced in the interior of a pulverulent mass confined by a wall sufficiently firm to prevent any disturbance of the particles. In this state the friction of the various strata on each other is generally less than in the other; just as, in a solid body in elastic equilibrium, the strains remain always less than those which would produce permanent alteration of its structure; the particles are then retained in position by their mutual actions less forcibly than if the wall were to give under their pressure, and they exercise upon it a thrust greater than the formulæ of Rankine and Levy give. This is the kind of equilibrium studied in the memoir. It is called "elastic equilibrium" because the pressures induced depend on certain small deformations, which the mass, supposed at first homogeneous and without weight, would undergo if it became, as it really is, heavy.

The bodies in question occupy a position midway between solids and fluids; for whilst solids and fluids, submitted to pressures varying from zero to considerable intensities, oppose to any given deformation a constant force—finite for the first, zero for the second—pulverulent bodies resist change of form with an energy so much the greater as the mean pressure to which they are subjected is greater; fluids almost when not compressed, they become rigid like solids under pressure. Their co-efficient of rigidity (*co-efficient d'élasticité de glissement*—Lamé's μ), instead of being constant, as in the case of solids, or zero, as in the case of fluids, appears to be proportional to the mean pressure p to which they are exposed. The author deduces this from the expressions which represent in isotropic bodies the mean of the principal elastic forces (*i. e.* the mean pressure p with its sign changed) and the differences of these forces, in terms of the three principal deformations, δ_1, δ_2, δ_3. Retaining in all the results the terms of two dimensions in δ_1, δ_2, δ_3, and expressing that the matter under consideration ceases, for finite values of δ_1, δ_2, δ_3, to be subject to the action of tangential elastic forces when p is zero, he finds that the normal and tangential components, N_1, N_2, N_3, T_1, T_2, T_3 (according to Lame's notation) of the pressure, per unit of area, on three elementary planes perpendicular to the axes, have the values (provided they do not exceed certain limits)

$$N_1=-p\left(1-2m\frac{du}{dx}\right),$$

$$T_1=pm\left(\frac{dv}{dz}+\frac{dw}{dy}\right), \text{ \&c.,}$$

where m is a constant positive co-efficient of considerable magnitude, and where u, v, w designate the molecular displacements parallel to the axes of x, y, z. The same analysis proves that the cubic expansion (dilatation) may be neglected in comparison with the three linear expansions to whose algebraic sum it is sensibly equal, or that the condition of incompressibility $\frac{du}{dx}+\frac{dv}{dy}+\frac{dw}{dz}=0$ holds. The remaining three equations between the N's and T's necessary for determining n, v, w and p are

$$\frac{dN_1}{dx}+\frac{dT_3}{dy}+\frac{dT_2}{dz}+\rho X=0,$$

$$\frac{dT_3}{dx}+\frac{dN_2}{dy}+\frac{dT_1}{dz}+\rho Y=0,$$

$$\frac{dT_2}{dx}+\frac{dT_1}{dy}+\frac{dN_3}{dz}+\rho Z=0,$$

where ρ is the density of the mass, and X, Y, Z the components of gravity parallel to the axes.

The special conditions existing bounding surfaces are as follows: at the

1st. At free surfaces, the effective pressure on the outside layer is zero; for the atmospheric pressure around each grain does not influence the mutual action between it and contiguous grains.

2nd. At fixed boundaries (such as the posterior faces of retaining walls) which are sufficiently rough—as they generally are—to prevent motion in the particles adjacent to them, u, v, and w vanish; and in the case of a surface infinitely smooth, the normal component of the displacement and the tangential components of the pressures are zero.

The integrations of the equations are easy when the mass—of indefinite extent in all other directions—is limited above by a plane making an angle ω with the horizon. The states of equlibrium of a pulverulent mass bounded in this way are infinite in number, and belong to one of two series, according to the values given to two of the arbitrary constants, c, c', introduced in the integration.

Any system of parallel material straight lines, situated in a vertical plane perpendicular to that of the upper slope, changes, through the small deformations it undergoes, into a family of concentric conic sections, similar and similarly situated, the axes of which bisect the four angles which are formed by a vertical straight line and the line of intersection of the upper surface of the mass with the plane aforesaid. These conic sections become circles of very large radius for straight lines parallel to the slope, and are reduced to parallel straight lines when one of the arbitrary constants $c=0$.

There are, in particular, two systems of equidistant and parallel straight lines, originally at right angles and inclined, the one to the vertical, and the other to the horizontal, at an angle ε, which after deformation of the mass remain straight, parallel, and unchanged in length, but are turned with respect to one another through a small angle $\frac{\sin\omega}{m\cos(\omega-2\varepsilon)}$. The squares which they originally formed by their intersections become diamonds, and the ultimate form of the mass may be arrived at by supposing it originally divided into indefinitely thin layers, inclined at an angle ε to the vertical, which slide in their respective planes in such a manner, that if one be considered as fixed, any other situated at a distance D in front of it will be displaced downwards by a quantity $\frac{D\sin\omega}{m\cos(\omega-2\varepsilon)}$. The case in which $c=0$ comprises an infinite number of modes of equilibrium, since there still remains the arbitrary constant c', is the most interesting, as it is the only one in which, by properly determining c', the conditions existing at a boundary, whether smooth or rough, are found to hold throughout the extent of any plane cutting the upper slope in a horizontal straight line—in other words, inclined to the vertical at the angle ε; and it is the only one in which the particles in this plane remain immovable during the deformation of the mass. Hence equilibrium will still subsist, if the material on one side of the plane be replaced by a retaining wall having this plane for its posterior face. This is naturally the mode of equilibrium produced where such a wall really exists, and it will be the same for two directions of the wall at right angles to each other.

When, therefore, the posterior face of a retaining wall is rough, and inclined to the vertical at an angle ε, the settlement of the mass takes place by displacement parallel to the face, and is, as already stated, equal, for any particle, to the product of its distance from the face by the constant factor $\frac{\sin\omega}{m\cos(\omega-2\varepsilon)}$.

Admitting the existence of the special condition set forth above at the surface of the wall, the pressure R on an unit of area at a depth L (measuring along the face) and the angle Φ_1 which its line of action makes with the prolongation of the normal thereto, toward the interior of the wall, are given by

$$R=K\rho g L \quad \tan\Phi_1=-\frac{\sin\omega}{\cos(\omega-2\varepsilon)},$$

where $K=\frac{\cos(\omega-\varepsilon)\sin\omega}{\cos 2(\omega-\varepsilon)\sin\Phi_1}$.

If, on the contrary, the wall were mathematically smooth, the values of $\tan\Phi_1$ and K would be 0 and $\frac{\sin\varepsilon}{\tan(\varepsilon-\omega)}$.

The total pressure P on an unit of

width of the wall is $\frac{1}{2}K\rho g L^2$ (where K has one of the values given above) and the point of application of its resultant, whose direction is parallel to R's, is at a depth $\frac{2}{3}$ L (L being in this case the total height of the wall measured along the face $= \frac{h}{\cos \varepsilon}$).

In obtaining these results the limit of elasticity of the matter has not been taken into consideration. Now, just as in solving the problem of the equilibrium of a perfectly elastic solid, under the action of given forces, it is necessary to express that the greatest deformation at any point must be less than that which will cause a permanent set, so it is necessary, in this case, to express that the greatest linear extension at different points of the mass must not exceed that limit which it cannot surpass without danger of disruption (*éboulement*).

Pulverulent bodies, being without cohesion, are incapable of transmitting tensions, whence it follows, by the analysis, that the greatest linear extension δ_1, must be less than the ratio $\frac{1}{2m}$. The limit of elasticity, being thus less than $\frac{1}{2m}$, can always be expressed in the form $\frac{\sin \Phi}{2m}$, where Φ denotes an angle (lying between 0 and $\frac{\pi}{2}$ generally) whose value for each particular kind of matter must be determined by experience. This angle may be called the angle of internal friction of the mass.

It therefore appears that the only states of equilibrium possible are those in which the condition $p>0$ and $\delta_1 > \frac{\sin \Phi}{2m}$, expressing the imperfect elasticity of the matter, are satisfied.

A first consequence of the imposition of these new conditions is to make the constant c vanish, *i.e.*, to reduce all the possible modes of equilibrium of an indefinite mass to those which can subsist in a mass bounded by a plane wall, and further, such modes of equilibrium, which then depend on a single parameter ε, say, are shown to be possible only when $\cos^2(\omega-2\varepsilon) \geqq \frac{\sin^2\omega}{\sin^2\Phi}$.

Their number, unlimited so as long the inclination of the upper slope to the horizon is zero, becomes more and more restricted as that inclination becomes greater, and when $\omega=\Phi$ they are reduced to one only; when ω exceeds Φ equilibrium becomes impossible. Thus the theory explains the impossibility of a pulverulent mass existing with a slope whose inclination exceeds the angle of friction of the matter of which it is composed.

The formulæ already obtained depend on special conditions, and relate to the case of a mass, originally without weight and free from pressure, which, on becoming heavy, takes a new state of equilibrium without the layer next the retaining wall having moved, if the wall be rough, or having moved out of its own plane, if it be smooth. Practically, however, in forming such a mass against a rough immovable wall already built, the particles contiguous to the wall only remain stationary so long as they are but slightly compressed. But the addition of successive quantities of earth or sand subjects them to increasing pressure, and causes them to move through finite distances, the result being an entirely different state of equilibrium. This state is that in which the internal stability of the mass is greatest, or in which the maximum extension δ_1 has at each point its least value compatible with the degree of resistance of the wall. The analysis shows that δ_1 attains its minimum value $\pm\frac{\sin \omega}{2m}$ when $\varepsilon=\frac{\omega}{2}$. This, then, is the value of ε which corresponds to the most stable state of internal equilibrium.

If, however, the wall is not sufficiently firm to allow of the mass attaining its maximum stability, the state of equilibrium produced is that in which the whole resistance of the wall is utilized. In these cases the value of the parameter δ, which defines the mode of equilibrium, is determined by the relation

$$\tan 2\varepsilon = \frac{\cos 2\varepsilon_1 \cos 2(\omega-\varepsilon)-\cos 2\omega \cos 2(\varepsilon_1-\varepsilon)}{\sin 2\varepsilon_1 \cos 2(\omega-\varepsilon)-\sin 2\omega \cos 2(\varepsilon_1-\varepsilon)}.$$

Whether the stability of the mass attain its maximum or not, the direction and intensity of the resultant pressure on a wall inclined at an angle ε_1 to the vertical are given by $P=\frac{1}{2}K\rho g L^2$.

where $$K = \frac{\sin\omega\cos(\omega-\varepsilon_1)\cos 2(\varepsilon_1-\varepsilon)}{\cos 2(\omega-\varepsilon)\sin\Phi_1}$$

$$\tan\left(\Phi_1+\varepsilon_1-\varepsilon+\frac{\pi}{4}\right) = \frac{\tan\left(\varepsilon_1-\varepsilon+\frac{\pi}{4}\right)}{\tan^2\left(\frac{\pi}{4}-\omega+\varepsilon\right)},$$

by substituting for ε its proper value.

All these modes of equilibrium are stable; for the wall may be supposed without weight, but held in position by an externally applied force, and by the pressure of the mass which it supports. If then the wall were to move towards or from the mass, the pressure of the latter upon it would increase or diminish, and this would exceed or be exceeded by the external force, so that the wall would tend to return to its original position.

Hence it is not necessary to make the thickness of a retaining wall greater than will enable it to support a pressure slightly exceeding that which corresponds to the least stable state of equilibrium.

Assuming the posterior face of the wall to be vertical (in which case the direction of the resultant pressure will be parallel to the upper slope) and Φ to be $= 45°$, the following table gives the greatest and least numerical values of K for different values of ω.

TABLE I.

	$\omega=0°$,	$\pm 10°$,	$\pm 20°$,	$\pm 30°$,	$\pm 40°$,	$\pm 45°$
Greatest value of K	.1716,	.1765,	.1935,	.2320,	.3404,	.7071
Least " " "	1,	.9848,	.9397,	.8660,	.7660,	.7071

The equilibrium of such a mass will therefore be stable provided the wall can support a pressure, applied at one-third of its height, parallel to the upper slope, and slightly greater than $\frac{1}{2}K\rho g L^2$, where K has the values .1716, &c.; but in order that the most stable state of equilibrium may be realized, the values of K must be taken from the lower line in the table.

For example, a retaining wall of rectangular cross section would tend to turn about the front edge.

In order to determine the condition of equilibrium it is necessary to equate the moment of the weight of the wall about this edge to the moment of the pressure of the mass (P) about the same axis.

Calling ρ' the density of the wall, b its breadth, and h its height, the weight of an unit of length will be expressed by $\rho' g h b$, and its moment about M_1 by $\frac{1}{2}\rho' g b^2 h$. The point of application of the pressure P will be at one-third the height of the wall, and the direction of its line of action parallel to the upper slope, its moment about the turning edge is therefore

$$\tfrac{1}{2}\rho g h^2 K(\tfrac{1}{3}h\cos\omega - b\sin\omega).$$

By equating these expressions, and reducing, the value of the ratio $\frac{b}{h}$ is found to be

$$= \tfrac{2}{3} \times \frac{1}{\tan\omega + \sqrt{\tan^2\omega + \frac{4\rho'}{3\rho}\frac{1}{K\cos\omega}}}.$$

1. Suppose the thickness of the wall is to be just sufficient to insure equilibrium, and assume for ρ' the value $\frac{3}{2}\rho$, which will not in general be far from the truth, then, substituting for K its numerical value from the upper line of Table I., the following results are obtained for

	$\omega=0°$	10°	20°	30°	40°	45°
$\frac{b}{h}$ (minimum stability) =	.1953	.1866	.1802	.1761	.1786	.2060

2. If, on the contrary, b is to be such that the most stable mode of equilibrium may subsist, the value of K must be taken from the lower line in the table, and for

	$\omega=0°$	10°	20°	30°	40°	45°
$\frac{b}{h}$ (maximum stability) =	.4714	.4107	.3486	.2887	.2325	.2060

A consideration of these figures proves that the practical rule of making the thickness of a retaining wall equal to one-third of its height insures in general sufficient stability.

The author then proceeds to examine the condition of the mass when disruption commences, and deduces the equations relative thereto. He also obtains in polar co-ordinates the equations applicable to the limiting state of equilibrium of a mass, plastic or pulverulent, submitted to pressures very great in comparison with its weight.

ELECTRIC RAILWAYS.

From "The Builder."

To predict that the locomotive engine will have its day—that, like some of the gigantic forms of the geological series it will attain its widest development only to fade away and die—would be a hazardous prediction. It would not, however, be more bold than was the original prediction of George Stephenson, that he would make a steam coach that should run at twenty miles an hour. That anticipation, indeed, was thought to be so rash that it could not be entertained by any sane and well-balanced mind. And yet, within ten or fifteen years of its utterance, Brunel was designing engines to run at 100 miles an hour; and made them to go, and steadily worked a portion of the traffic of the Great Western Railway, at a running speed, over more than twenty miles of line, of seventy miles an hour, which is about the speed of the great senegal swift on the wing.

So rapid and so successful has been the growth of the locomotive engine, that its admirers may well hold that it promises to be the motor power of the future, as well as of the present. And there is no doubt that immense advantages attend on the method which has wrought such a revolution in our means of transport. But the locomotive has certain great disadvantages with which to contend. The mode of thus applying power is extremely costly. The actual resistance of the engine ranges from a weight equal to that of the rest of the train to about a fifth of that proportion. To move that weight is not only costly in proportion to the ratio between train and engine, but is so in a much higher proportion; as the friction of the automatic engine is much greater, per ton, than is that of the propelled train. Allowing equal figures for atmospheric resistance, the constant for the friction of the engine is usually calculated at about double of that for the train. But we have a more exact mode of ascertaining the cost of locomotive power, and that is one as to which it is very remarkable that it has been hitherto so far left out of sight. On the Blackwall railway, at the time when it was worked by ropes, observations were made as to the power absorbed by the loaded, and by the unloaded rope, the difference between the two being that due to the weight of the train. This was only 21 per cent. of the whole. The cost of working per ton per mile, according to data given by Mr. Robert Stephenson, was 0.1875d. This is less than the cost of working any railway in England in the year 1879, with the one exception of the Manchester, Sheffield and Lincolnshire line, in which the cost is at the minimum, not owing to engineering consideration, but because the traffic is so much more equal in both directions than is the case in any of the great trunk lines leading to the metropolis. The great source of waste, the return of empty wagons, is thus avoided. As closely as we can calculate, the average cost of railway transport in the United Kingdom in 1879 was a little over one-fifth of a penny per ton mile of loaded train, not including the weight of the engine and tender. But the Blackwall cost, for moving loaded trains alone (the cost of the apparatus being deducted) was 0.4d. That is the cost of what was anticipated to be a very costly mode of propulsion (although it was in the first place thought to be preferable to the use of locomotives). We find that the consumption of power by the stationary apparatus was about four-fifths of the whole power exerted. And we are thus led to the conclusion that four-fifths of the power of the locomotive is consumed in the propulsion of itself and of its tender.

A bit of positive experience such as this adds great point to the value of any attempt to substitute for the locomotive a means of propulsion that has a fixed point of resistance. The attempt was made, years ago, by the projectors of the atmospheric railway. Some of the first engineers of the day—Isambard Kingdom Brunel in this country, and Eugene Flachat in France—entertained a high opinion of the feasibility of this plan; and not only so, but backed their

opinions very heavily by their purses. And it should be more generally known than is the case that it was not to the mechanical difficulties of the problem, great as they admittedly were, that the final abandonment of the scheme was due. A speed of sixty miles per hour was attained on the atmospheric railway between London and the Croydon; and the Dublin and Dalkey Railway was regularly worked on this system for many months. The real cause of failure was the rapid entrance of the terrestrial heat into the exhausted tube, thus raising the resistance of the rarefied air to a tension almost equal to that of the external atmosphere. Thus, the stationary engines on the South Devon Railway were actually pumping heat out of the earth. They became nearly red hot in the process, which was like that of baling water by a sieve. Nor is it probable that this physical obstacle to atmospheric propulsion against an artificial vacuum can ever be successfully overcome.

Messrs. Siemens have lost no time in endeavoring to apply the greatest discovery of modern times—probably the most important physical discovery ever made, that of dynamo electricity—to locomotion. In our opinion, the attempt deserves the most careful and patient attention. The difficulties to be overcome, as in the former case, are not so much mechanical as physical. That the former obstacles can be vanquished, Messrs. Siemens will say, is no longer matter of doubt. They can point to the actual speed of some ten miles an hour attained by their electric locomotive and its miniature train in the grounds of the Crystal Palace. The main difficulty here —and we are not among those who regard it as insuperable—is that of conduction. This is *the* great question, on which, as we have more than once intimated, the future of the industry of mankind depends. It here presents a new "case" to the student. It is a difficulty which opposed the introduction of the electric light, and which has been, already, to a great extent removed, as far as it opposed an obstacle to science. It is the primary question of electric conduction. The working of a line of 300 yards in length does not give much information as to the mode in which a system that may work admirably for such a distance, can be extended for a distance of 300 miles.

In the experiment at Sydenham the motor power is supplied by a stationary engine of eight-horse power nominal, which drives, in the ordinary mode, a dynamo-electric machine. The electric current induced is conducted along a rail laid in the middle of the track on which the trains travel, which is partially insulated by being laid on wooden blocks. The return current passes through the exterior, or bearing, rail. The locomotive is a Siemens dynamo-electric machine, mounted as a propeller, and as acting as a sort of counterpart to the fixed dynamo-electric motor. The current produced by the latter, and sent into the central rail, is taken up by brushes of iron wires attached to the locomotive; and thus causes the appropriate part of that apparatus to revolve. Having thus done its work, the current escapes through the metal wheels of the truck to the exterior rail.

It is evident that this is a bold and beautiful application of the principle of the electric telegraph. Correspondence of action between two portions of apparatus, placed in electric communication, is effected in each case. In one, motion is communicated by one stationary machine to another. In the other, motion is communicated from a stationary to a corresponding movable engine. The fact that a much larger development of energy is applied in one case than in the other does not affect the principle. Nor does it, so far as the dynamo-motors are concerned, affect the promise of success. We do not see why the same principle which moves a ray of light, by an impulse sent through 3,000 miles of cable, should not be applied to the movement of a train of 1,000 tons, so far as the mere reciprocal action of the dynamo-motor is concerned. The knot of the question does not lie there. It is concealed in the center rail. It regards the transmissibility of the power. As to this, a little line of 300 yards tells us little. The point which most disappoints us is, that so long a time has now elapsed since Sir W. Thomson and Dr. Siemens both expressed their opinion as to the transmissibility of enormous doses of electric force through conductors of a certain magnitude, without more having

been said or done on the subject. It is with this question of transmissibility of power that the industry of the future is bound up. So long as distance is sharply limited in this respect, coal will continue to be the main source of mechanical power. It is a costly source, and it is one of which the cost depends greatly on locality. If, for example, ten miles should prove to be the extreme distance for which 40-horse power or 50-horse power of energy can be transmitted electrically without enormous loss, coal will for the present hold its own. If the question should be answered in the opposite sense, the reign of King Coal is not more assured than is that of certain potentates of more ancient dynastic rule, although of less remote pedigree.

THE GUN QUESTION.

From "The Engineer."

The information recently supplied to the House by Mr. Trevelyan, and the questions asked by Mr. W. H. Smith, have naturally brought up again the question of the rival systems of construction of ordnance. It is urged with much force that we need a large supply of powerful breech-loading guns, and that it is desirable to have it with as little delay as possible. If, then, a really good and powerful new type gun can be obtained without doubt at once, it seems wise to take the responsibility of immediately giving an order. This appears to be the case. The Elswick firm, who have really taken the lead in the development of new type guns, have actually had their ordnance under Government trial for the last two years. They have fired their guns with an enormous amount of stored-up work in them, and the trial has been very successful. Does it not appear reasonable and fair to them to begin by ordering guns from them? We ask this question, not as a preliminary to contradiction, because we do not see cause to contradict it. We think, if a certain number of guns are immediately wanted, it is reasonable and right to give the preference to those who stand in the position held by Elswick. This, however, is not the last word to be spoken on the question. While we believe that in the investigation of the problem how to burn powder to the best advantage, England has been well to the front, it has happened that the conclusions we arrived at were not, on the whole, favorable to our own service guns. In the development of length our quick-burning powder originally placed us at a disadvantage; so did muzzle loading. Hence it is that we need to bestir ourselves to equip our navy afresh. We are almost tempted to digress here, and point out that the small number of inferior guns carried in our ships of war further tells against us. Speaking generally, we carry much fewer guns of medium size than the French. Perhaps, we were right when our armor was able to defy the power of such guns; but directly it becomes possible for a medium gun to pierce our sides, everything is changed. So far, then, there is much in favor of vigorous action.

We have, however, considered only the length, proportions, and method of loading our guns. Where so much has recently been developed, has anything happened to bring up the question of actual construction? If so, seeing that we are likely to make a large number of guns for our service, surely special attention deserves to be given to this. Now, we all know that where great efforts are made to increase power we are sure to learn the measure of strength we possess, and especially has this held true in this country; because we have enlarged the chambers of our guns to a great extent as a substitute for deficiency in length. But chambering a gun is likely to bring a peculiar kind of strain on it. The surface at the bottom of the bore being increased, the gun's projectile will stand in a mechanical relation favorable to its discharge, but throwing increased longitudinal strain on the gun. This, with other causes, may have contributed to some of the results which have occurred. As a matter of fact, at all events, we have had more notorious instances of guns made in this

country bursting or yielding during the last two and a-half years than we have known since the first introduction of built-up ordnance. As we pointed out in a recent article, there is reason to fear that confidence in our guns is much shaken abroad, and that Krupp supplies guns where English ordnance used to go, even in vessels fitting out in the Thames. We especially wish to avoid raising the question of any particular accident. We only speak generally as to broad facts. We will suppose that it was perfectly right and natural that every gun should have yielded as it did; that we are convinced that the Thunderer gun was bound to protest against double loading; that the 100-ton gun showed how safely and gracefully a monstrous gun could pull asunder; and that the Angamos gun lies safe and sound, minus its trunnion ring, waiting to assert its innocence and strength whenever it may be fished up. Supposing all this, which has much to support it, the fact remains that steel guns have not had attention called to them in this way to the same extent latterly, and no one can pretend to say that our own service system stands as high as it did. Five years ago it was held that steel guns were liable to burst very dangerously, and those of wrought iron only to rend open under any strain. It would be difficult to maintain this in the presence of the fragments of the two Thunderer guns. Or if we go so far as to make special allowance for guns whose charges were exploded under compression and with exceptional violence, yet many will not do so. Rightly or wrongly, our wrought iron system of construction has had its reputation questioned abroad and at home. We do not mean that powerful guns cannot be made on it, for most of the very powerful guns existing are actually made on it. We do say, however, that immediate supplies of guns should be limited, and the whole question of construction should be fairly tried. If Elswick deserves consideration for the leading part it has taken in bringing out new type guns, may not the same plea be urged for Whitworth and Vavasseur for developing the manufacture of steel guns? If steel is good, the country will reap the benefit of the efforts made by private firms in the teeth of sweeping condemnation and discouragement. As we have pointed out, steel now claims the very qualities that caused us originally to give the preference to wrought iron. Personally we look upon steel as liable still to deceive. It has ways that need to be better understood yet, and we could quote examples of guns in support of what we say; but we may fairly question whether steel may not be proved to have powers so far in excess of those of wrought iron that a built-up gun may be made with sufficient margin to cover any danger arising from uncertainty, and yet able to bear more than our present service guns. Lastly, on the other hand, we have Sir W. Palliser's guns adopted on a sweeping scale on the other side of the Alantic—guns which have never been fairly burst, or anything like it, to our knowledge.

We have not the slightest wish to contrast our own system unfavorably with these. We only urge that its credit is so far questioned that we have no right to be satisfied without a trial. If we had either of the other systems in the service we should plead equally for this. Even from the point of view of our own Gun Factories and that of Elswick, we should urge a fair trial. Perhaps, of the two, Elswick is specially responsible for the confidence placed in our present system. We hear of an officer urging a plea somewhat in the following language: "You may set us down as prejudiced, but look at Elswick. Armstrong and Noble are not fools. Their credit and profits depend on the excellence of their guns, and they prefer the same system that we do." Clearly the question can only be settled by a thorough trial, and we trust that the country will be satisfied with nothing less. If our present system is the best, it will be well worth our while even pecuniarily to prove it so abroad. Our private factories really save us the necessity of having two or three Arsenals. It is important for their credit that they should be demonstrated to have guns capable of competing against the world. Let such a competition be invited. We are supposed to have a new committee deserving of extraordinary confidence. We have the highest authority for assigning to them independence tempered with discretion.

THE USE OF MILD STEEL FOR SHIPBUILDING.

By M. MARC BERRIER FONTAINE, Chief Constructor of the French Navy.

"Nautical Magazine."

After referring to the numerous papers which have been written on mild steel and its applications in England, the author described the parts played by France and England in the manufacture and development of mild steel, and its employment for shipbuilding amongst other work. He then went on to describe the chief elements of successful manipulation of mild steel, the principal of these being the necessary great skill on the part of workmen, who need to be encouraged in spite of the failures due to the want of experience in dealing with the new material. He next went on to consider the importance of having special tools for dealing with mild steel for shipbuilding, and especially of mechanical arrangements for taking the plates from ovens and quickly depositing them on the tables or dies upon which they have to be shaped, so that the work may be done without hurry and whilst the plate is still red hot. Much stress was laid on the use of gas ovens on the Gorman system instead of furnaces on Siemens' system for heating plates for hot bending, the Gorman oven being simpler in construction and management. At Toulon, as soon as a piece of metal is brought to a fitting temperature, it is seized in the oven by pincers, to which a rope is made fast, which, passing over other return pulleys, passes to one of two capstans. A workman starts this by pressing his foot on a lever close to the ground, a few turns of a Brotherhood engine being enough to get the piece thus drawn on to the plates alongside of the guides upon which it is to be moulded; one of its ends being quickly fitted against these guides, the other end is clutched by a claw which is hauled upon by a cord seized upon one of the capstans. Wooden mallets and swages are used for almost all the work, but when excessively sharp curvatures, &c., are needed, and hammers have to be used, the work is afterwards carefully annealed. Annealing is not otherwise resorted to, as the work is still at a color heat when finished.

The use of hydraulic presses gives the most satisfactory results when applied to the work of fitting and moulding angles or other work with sufficiently open curvature to admit of their being done cold. This is the case with all the deck beams, as well as for the greater part of the angles of the longitudinal stringers, and also for a very large proportion of the angles of the frames. At Toulon this work is performed by presses of graduated power from 5 tons to 100 tons, some vertical, some horizontal, to suit all possible cases. One press of a hundred tons is quite sufficient for straightening and moulding double Tee-bars of iron of 350×150×15 mm., and of steel bars of 300×148×14 mm. The profiles of these are among the most rigid forms of all those yet dealt with. A press of 50 tons is sufficient for straightening and moulding almost all the other forms used, from that of H or double Tee bars of steel of 450×130×10 mm. Finally, the small 10-ton presses can easily mould steel angles of 150×150×15 mm., and 5 ton presses will mould steel angles of 120×120×12 mm. The consideration of the effect of ragged holes and punched edges has led the authorities to forbid the use of the punch for making cuts in the plates, whether straight or curved, by a string of holes. In that respect the exceptionally large stretch of the Toulon hydraulic shears, which is 1.50 meter, or 5 feet, allows the shearing of the largest plates in any direction, and to cut sheets of any length up to 3 meters wide straight across. Curved cuts are obtained at once by means of a series of blades having graduated curvature, and brought sufficiently close to one another for them to cut out with sufficient exactness all shapes which can occur, whatever be their curvature. A collection of bent blades of this kind makes an outfit which is extremely valuable. The cutting edges of these blades

are spiral, as in Kennedy's spiral punch, thus having a shearing action. For splitting the ends of channel and other bars in the way often required for junctions with deck and flooring framings in ships, shears which are really long narrow punches working in long slot dies are employed. Cutting thus takes place on both edges, and the bars are not distorted. It may be said generally that the tools which carry out most exactly the work which has to be done, whatever it may be, are at the same time those which least upset the neighboring portions of the pieces of work upon which they act. Care is taken that the working angles of these different tools are set as may be most suitable for each kind of work. The most rigorous and the most unceasing attention is given by the fore men and by the workmen themselves to seeing that the cutting edges of their tools should always be kept in the most perfect condition. In order to secure this, grinding machines, with artificial emery grindstones specially arranged for setting the tools of various forms, are largely employed; these machines securing a regularity and a precision of edge which it would be impossible to obtain by hand. These emery grindstones are also used for taking off burrs, and finishing both plate work or moulded bars, as well as in finishing the small forged pieces, such as ring bolts, staples, hinges, and so forth, which form so large a part of modern construction. A saving of 22 per cent. has been found to be the result of long-continued trial of twist drills properly ground with emery wheel machines. The improvements in the results obtained by great care in every phase of the making of plates and moulded bars of steel, has led the Constructors of the French Navy to consider the desirability of relaxing, by slow degrees, the severe requirements which had at first been imposed by them for the execution of work of every description to which the plates and moulded bars of steel should be submitted in the dockyards. The cases in which it is judged necessary to anneal steel plates and moulded bars are now incomparably less frequent than they used to be a few years ago, and the number is still undergoing daily reduction. A return by degrees is being made to the use of the simple punch, without annealing, and without riming, for cutting holes in almost all the pieces of framework of the new constructions, reserving the use of the drill for those pieces only in which there is special reason for keeping up the greatest possible strength, having regard to the more important position that they have to take in the construction, or the exceptional strains they may have to bear. The vigorous precautions which the want of homogeneity at one time enforced are being discarded, and the most recent trials appear to prove that the loss of strength in punching and working is not much greater for steel than for iron. M. Fontaine therefore, with very cautious enthusiasm, remarks: "It seems to me, therefore, to be beyond doubt that at no distant period—as soon as the breakage of steel work becomes sufficiently rare not to require greater precautions in working these pieces than those which are applied to iron, that is to say—we shall very soon get into the way of punching nearly all the steel plates and moulded bars, and of only annealing them in exceptional cases, when they may have been submitted to very violent, and very trying deformations—a treatment, in fact, precisely similar to what we give to iron under the same circumstances." Owing to the more complete homogeneity and ductility of the steels, and also to the increased practice workmen have acquired with the new metal, the welding of steel plates and bars can now be effected as easily, as simply, and as satisfactorily as that of similar work in iron, without, M. Fontaine says, its being necessary to have recourse to any special process or to the use of any particular flux. "A great number of weldings of steel plates and angles have been broken as tests, and the results of these tests, in which the fracture often takes place outside the weld, have finally led us to consider the welding of thin plates of steel as being as certain and perfect as that of similar pieces of iron."

The author stated that the tensile strength demanded and the inferior limit imposed by the French authorities for steel plates and bars of various section were not the same for all thicknesses and sections, but were greater for the smaller and thinner sections. Excluding boiler iron, for which an exceptional

amount of ductility is considered indispensable, the inferior limit of tensile strength required by the French Navy is as a general rule higher than that specified by the English Admiralty, by Lloyd's Registry, and even by the Underwriters' Registry. It is only, in fact, for the thicker plates of from 20 to 30 millimeters, and for the stringers and butt straps of all thicknesses, worked across grain, that the French Navy allows a low limit of 44 kilogrammes per square millimeter, or of 28 tons to the square inch. This is specified for, all through by the Underwriters' Registry for all steel used in the hull. As the thickness of the plates diminishes the inferior limit required in the French Navy increases progressively, and for plates of from 6 to 20 millimeters in thickness, which includes nearly all those used in modern constructions, this limit already exceeds by 1 kilogramme per square millimeter that of the Liverpool Society. In order to be accepted for use in the French Navy, thin plates from 1 to 4 millimeters thick must be subjected to a minimum test of 30 tons to the square inch, or 47.25 kilogrammes per square millimeter, while the minimum tensile strength of the stringers and butt straps tried along the grain, and that of bars of all sections with the exception of double Tee-bars, Tee-bars and bulb-iron, should be of a still higher tensile strength, namely, 48 kilogrammes in place of 47.25 kilogrammes per square millimeter. In the French Navy there is no superior limit to the tensile strength of steel presented for acceptance, so that the total effect of the conditions required by it has had the effect of furnishing it with steel plates and bars having an actual tensile strength very considerably in excess of those of the similar pieces of steel which are used in the same work in the building yards of Great Britain. This superior tensile strength is not bought in the French Navy at the cost of a reduction of ductility in the steel there employed, for a mimimum elongation of 20 per cent. is demanded.

As regards the calculations of tensile strength, it appears from the results of the numerous experiments that a mean figure of 48 kilogrammes per square millimeter, representing the ordinary breaking strain of steel plates and moulded bars such as are actually used in the French Navy, is adopted. The usual breaking strength of the iron plates and moulded bars of ordinary and common quality which are delivered to it, cannot, on the other hand, be regarded as greater than 36 kilogrammes per square millimeter at the outside. For iron a factor of safety of 6 is used. Using the same factor for steel it is reckoned that plates and moulded bars of this metal may be safely loaded with 8 kilogrammes per square millimeter. The limiting loads of 6 kilogrammes for iron and 8 kilogrammes for steel, are to one another as 1 : 1.33, consequently the inverse ratio of 1 to 0.75 indicates the reduction of thickness, and therefore of weight, which the substitution of steel for iron allows us to introduce into the plates and moulded bars which we use. This corresponds to an economy of 25 per cent. in weight. In order to take account of the loss of strength experienced during the work—a loss which may well be of greater relative importance in steel than in iron—and in order to take account of the existence of an inferior limit below which we cannot reduce the thickness of steel plates without risking their buckling, and although there does not exist any general formal rule about this, the Constructors of the French Navy, in agreement with the authorities of Lloyd's Registry, think that it is not safe to reckon on a final saving of more than 20 per cent. in the replacing of iron by steel in the weight either of the whole hull or of any part of it.

M. Fontaine then described at some length the experiments by the French Navy, which have shown that steel corrodes more rapidly than iron, and he concluded: "It would not be safe to affirm very positively, for instance, that this extremely rapid corrosion of steel plates is solely due, as Mr. Barnaby assumes, to intense galvanic action arising between the metal and the black oxide by which it is covered, and that consequently it will be sufficient to clear the plates of this black oxide by means of a weak acid bath in order to make their oxidation in sea water slow and uniform, like that which usually takes place on the surface of iron plates. It could not be affirmed with any certainty either that the greater or less rapidity with which

steel plates are attacked by rust depends solely on the greater or less proportion of manganese which they contain, as has been suggested by Dr. Siemens in 1878, in a paper read before the Institution, a suggestion, however, thrown out with some degree of doubt. Finally, it cannot be affirmed, as has been recently stated, before another society, that the corrosion of iron and steel plates is the more slow and regular in proportion as those plates contain a greater proportion of carbon or phosphorus, and that it is consequently not possible to find plates which possess the necessary ductility in combination with the valuable property of being attacked by rust only in a slow and regular manner when exposed to sea water." The French contractors consider that the cases in which steel rivets have hitherto been used do not seem to them sufficiently numerous, nor does the experience which results from them appear to them to have been sufficiently extended, nor sufficiently conclusive, to allow them to consider themselves in a position to dispense with the use of iron rivets.

The discussion on this paper was opened by Dr. Siemens, who repeated that mild steel corrodes no faster than iron, while others hold to the general sense of the above remarks of M. Fontaine. He also spoke of the rapid corrosion caused by the use of two metals such as steel plates and iron rivets. He also quoted some recent experiments by Professor Kennedy to show that mild steel was increased in strength by punching. Mr. White remarked that in punching strips it was well known that the material which was left at the sides was stronger as the hole was larger, as though the material was strengthened by the strain imposed, as iron or steel rods are by slight stretching. He also referred to the very complete machinery used by M. Fontaine for working steel cold, and to the numerous sections in which steel could be obtained in France, making hot work less frequently necessary. Mr. West said that pitting was often the result of the mechanical removal of paint covering, and that after a time corrosion gradually grew less and was no more than in iron. Harder steel, he observed, was gradually coming into use, and had increased in use since his paper on the subject.

THE BUILDING ARTS OF INDIA.

By GENERAL MACLAGAN, R.E.

From "The Building News."

Every one who has been in India has had opportunity, at some time or other, of taking notice of the buildings in the places at which he has had to take up his abode for a time. He may, indeed, be often in places where there is not much to be seen. The ordinary dwellings of the people will not in India, more than elsewhere, present much that will be thought worth observing. Yet, even in the simplest of dwellings, one may see how much can be made of very slender local resources, and how well, under the guidance of ancient custom and personal experience, they are turned to account. When you hear of cottage walls made of mud it does not sound nice to English ears. But, when you see it, you find it is something better than you thought. Put together solidly and thickly, it becomes one mass throughout, and, hardening as it dries, it forms a compact and effective protection against heat and against rain. In greater mass, this simple material forms the very efficient defensive works of what are well known as mud forts in India. How simply, also, do we find roof protection supplied by a skillful use of the common reeds and grass that grow in the jungle (jungle, let it be observed, is the familiar name both for forest and all uncultivated waste, which, except in driest tracts, commonly becomes a wilderness of shrubs and thorny trees and tall grasses). A roof covering of reeds, of no great thickness, does not truly afford much protection against the sun, and will not exclude the heaviest rain; but it is very wonderful to see what it can do. At places in the hills, you shall

see local material of another kind turned to account for roof covering, in a cheap and effective way; large flat slabs of easily-split stone, doing duty as slates, with lumps of rock laid upon them to hold them in their place. In India, as in most other countries, there is something worth noticing in the way in which the simplest of available means and materials are turned to account in very simple ways. In India we notice next something more. When we get above the very lowest and poorest kinds of human habitations, we begin to see manifested a demand for some ornament. The ornament may be of a very rude character, but there it is. Something is wanted more than that the building shall serve its direct and essential purpose. You may find ornamentation given in color or in wood carving. The whitewashed door-jambs may have streaks of ochre, diversified with curved lines and spots, and sometimes more ambitious efforts of the owner or the village artist. But there is something of a higher class in the rough carvings of the lintels and the door-posts of houses in even lowly, unpretending villages. Rough carvings, no doubt, they often are, of simple waving lines or geometric patterns, after the fashion of greater and more elaborate work in large cities. They are very unsymmetrical, perhaps, and very uneven. But this is nothing; the eye does not care to be critical in looking at these things. The ideas and aims are good, if the execution is something rustic. Rustic or not, the effect is very pleasing. It admits of variety of treatment, and the treatment rises to various degrees of excellence. But the great thing is that it is the expression of a felt desire for something more than mere needs. A something pleasing to the eye has become a need, and it finds, in its simple way, on the spot, the art that is capable of satisfying the demand.

There is often a sort of idea that one must go back a great way for specimens of excellence in various arts, and, among these, the arts connected with building. In India, as elsewhere, people have been in the habit of saying that no such buildings are erected now as in the days gone by, and that certain old arts are lost. It has been concluded that the capacity for such work has died out. It is one phase of the idea prevailing in all ages that former times were better. It may be the case that we cannot point to anything in India, built within the last hundred years, to equal the grand Hindu temples of Tanjore, the Jain buildings at Abú, the Taj Mahal at Agra, the Jama Masjid at Delhi. The occasion for erecting such buildings and the means are wanting. We are not warranted in adding, also, the ability to design and to execute them. It is almost needless to say that for great and beautiful buildings, great expenditure of money and labor is required. It was perhaps a stern necessity that stopped the second tower alongside the stately Kuth Minár at Delhi, and the second tomb opposite the Taj, and elsewhere left intended works unfinished. The ability was not wanting, but the means.

We are not fully able to say where the earliest building arts came from, of which we see the illustrations in India. There is nothing to show that any distinctive art of this kind was brought in by the intellectual race which, at a remote age, entered India from the northwest, and gradually extended southwards over their new country. There is reason to believe that they found architecture among the people of the south. In whatever way acquired, the Hindus have shown a very admirable power of forming a style, and working it with great variety of treatment, and great beauty of detail, though not always equal soundness of construction. No special reference is made by the historians of the Greek invasion to fine buildings in India at that time. But the mention of Taxila as a great and magnificent city, seems to tell of buildings at that place which were of some importance. And now we have there only the ruins or traces of numerous small Buddhist topes; and a few other remains, which are undoubtedly Greek.

Mohammedan architecture, which came in from the West, assumed more graceful forms in India than it had done in Persia. It developed other forms again when it traveled westward, and took root in Spain. Moreover, in India it adopted, in the time of the Emperor Akbar, and under the influence to some extent of his enlarged and liberal views, Hindu forms of ornament, as well as of construction, in works distinctly Mohammedan, and this in a manner very effective and beautiful.

And, similarly, in many parts of India, we find Hindu buildings of recent centuries adopting, with more or less success, Mohammedan forms of constructions, with corresponding ornament. They would appear to have something in common, in their fundamental ideas, which allows of these adaptations without marked fault. It is otherwise when we see Oriental forms trying to adopt Italian features, as at Lucknow, where, in some cases, the mistake is aggravated by the effort to make a good show with inferior means.

The dome and arch, borrowed by some modern Hindu buildings, are foreign to pure Hindu work. The construction was unknown to the earlier Indian builders. A well-known illustration of this is to be seen in the great gateway of the Kutb inclosure at Delhi, built in the earliest Pathan times. The arch-shaped entrance is not an arch, but the form is given by horizontal courses of stones projecting one beyond another, till they meet. It would appear that Hindu workmen, unacquainted with the arch construction, were employed to execute the work to a prescribed arch form. The same thing is to be seen in a covered passage at the ruins of Ránigatt, a Buddhist fortified monastery, a little beyond our Yusufzai frontier, to the west of Torbéla on the Indus, above Attok. Likewise in some old bridges in Orissa. The high pyramidal roofs of Hindu temples in the south of India have a dome-shaped crown, which is not a dome. It is scarcely necessary to say that the large Buddhist *topes*, the large buildings of the beehive shape, now pretty familiar from drawings and photographs, are not domes, but are formed on a solid core.

One of the most observable things in connection with the best of the old Hindu building and groups of buildings, is the attention that has been paid to choice of site, and the admirable skill with which the choice has been made. We admire the way in which English abbeys and monasteries found out lovely sheltered shops in which to plant themselves, in green and peaceful valleys of our own land. No less happy has been the success of the Hindus in the choice of situations for their buildings. Temples, in shady glens and on wooded hill-sides, have been placed where they have beautiful back-grounds of crag and forest, of rich color and of varied foliage. Such are numerous Hindu buildings, small and large, in Central India and Southern India, in Rajputana, in Kashmir, and elsewhere.

It is noticeable that Buddhist buildings, monasteries, temples and topes, or relic monuments, are many of them built on the open plain, even in the neighborhood of better ground, with no reason that is now apparent for the choice of their position. Other buildings of the Buddhists occupy, like those of the Hindus and the Mohammedans, commanding sites which seem to have been carefully selected. Some, at least, of those which stand on what we might be disposed to think chance sites, are connected with incidents in the traditional life of Buddha, which may account for the exact position in which they are built. And others probably have a similar history.

Our building predecessors in India did not meddle much with the large rivers. They had to build some defensive walls and terraces on their banks. Bridges, of course, they did not build across such rivers. Never till railways brought their demand for a continuous running line did the British Government attempt anything more than floating-bridges on these rivers in the plains. And when we consider the character of the rivers and the requirements of a permanent bridge, we have no reason to be surprised that even the wealthy Moghul princes and their engineers did not apply their strength and skill to works of this class, and were content, as their predecessors for many centuries had been, to use boats. The pier foundations of one of our railroad bridges were scooped away by the stream, at a depth of 70 feet below the river-bed. Another of these rivers, at a place where a railway-crossing is being built at this present time, has been known to rise, in exceptional floods, upwards of 90 feet above its low-water level. We can feel, in the face of facts like these, that it was right to let the permanent bridges wait till the days of railroads.

Over swift and rocky rivers in the hill country, which it was necessary to cross by a single span, suspension bridges of hempen ropes or cables made of birch-twigs have long been in use. On roads

where laden cattle were used, something different was required for crossing the rivers. The kind of bridge called *sanga* in the northern hills is a good and useful construction, for which the materials were commonly available. A number of beams, laid side by side, project from each bank of the river, slightly pointing upwards, firmly secured by being built into the bank, and heavily laden at the shore end. Another set of beams is made, in like manner, to project beyond these, and others again till the space left in mid-stream can be crossed by single timbers. It is, in fact, like the overlapping stone construction. On cart roads, where something more is wanted, there are no masonry bridges in large single spans by native builders, such as have now been built in British times. It may be of interest to mention that a few years ago, two brick bridges, each of a single arch, 140ft. span, were built (by Lieut.-Colonel James Browne, R.E.) over two of the rivers of the Kangra district in the Punjab, on the main line of cart-road along that beautiful valley.

In the choice of their materials, we see much to admire in the works of the native builders who have gone before us in India. In the most lively times of Moghul building energy, the free outlay on grand works brought costly stone from long distances, and well has their white marble and red sandstone been turned to account. The most ordinary building materials, being such as the earth supplies, have been the same in all ages. The difference in their use, at different times and places, consists in the choice that is made of the better or the worse, and in the means available, in money or appliances, for conveying what was selected to the place where it was to be used.

When we speak of power to convey what was selected to the place where it was to be used, we observe that in India this power is not often illustrated, as in some other countries, by great buildings constructed of enormous stones. This does not seem to have been one of the favorite ambitions of the builders whose work is now to be found in India. There are, of course, big stones in some buildings, but their bigness is on a different scale from that adopted in other lands, and is not such as to give rise to the admiration which we feel in seeing what has been done elsewhere. There is a big trough at Vizianagar, in Southern India, cut out of a single stone between 30 and 40 feet in length, but it is probable that it has never been moved from the place where it was made. There is a temple in Kashmir which is built of five stones, one for each of the four corner piers, with its portion of roof, and the fifth a square-pointed piece, which crowns it. But the whole building is not a quarter of the size of one of the big stones in the terrace wall of the temple at Baalbek.

The masonry of the outer inclosure walls and basements of certain Buddhist works in Northwestern India, perhaps the oldest masonry now standing in that part of the country, is of a pecular kind of effective roughness. It is without mortar. The large stones are unsquared. They have a tolerably flat face, but there has been no endeavor to make them fit each other. Between the stones are irregular gaps of varying width, which are filled in with pieces of slaty rock, all laid flat, and firmly driven home into these wide joints. There are many specimens of this kind of work in the Buddhist tract of the Punjab frontier districts.

There are likewise in India stone circles of upright blocks, like those well known in England and other countries In one of these circles near the village of Asota, Yusufzai, northeast of Peshawar, about 50ft. in diameter, the stones have been roughly hewn on two sides. Their greatest thickness is about 2ft., and the greatest height of any now standing is between 11ft. and 12ft.

It is remarkable how little (speaking generally) even the oldest buildings in India have suffered from exposure; and this exposure sometimes is of a very trying kind. The buildings bear testimony to the good choice that has been made of the stones used in them. A dark and hard blue limestone has been a favorite material with the Hindus. It receives fine sculpture, and retains sharp, well-defined edges. Much of the Buddhist sculptured work in the northwest of India, where sculpture is very abundant, is on hard clay-slate. The sculpture on these buildings is mostly on the interior faces. The Jain temples at Dilwara, on Mount Abú, profusely and beautifully carved inside, are of white marble. Out-

side, these buildings are of studied plainness, not as the Hindu buildings, great and small, in all parts of India, which carry much ornamentation outside; the largest of these—the magnificent temples of Tanjore, Trichinopoli, Tinnevelly, Madura, and other places in the south, of Nassik in the west, and of Orissa in the east — being covered throughout with elaborate carved ornament and sculpture. On the hills of the Salt Range in the Punjab (hills containing the great mines of rock-salt) are Hindu temples of a gray limestone, naturally of a somewhat honeycombed texture, which has suffered further from the weather.

In the great imperial cities of the Moghuls white marble and red sandstone have been largely used together, and with excellent effect. The marble is polished, and well withstands the weather. But though it suffers little from the weather, there is another kind of injury, very subtle and troublesome, to which it is exposed. However carefully and closely the stones have been laid, yet, into the joints between them, on domes and terrace roofs, on cornices and parapets, the seeds of shrubs and trees will find their way, and there begin to grow and thrust their roots beneath. The pipal tree is particularly insidious in this kind of attack on unwatched stone-work, and if allowed to stay, as we see it has been sometimes, it will slowly, but strongly, dislodge the stones, and, if there is water near the foot of the building, will push its long roots through the wall, and down towards the moisture that it seeks.

In the Mohammedan buildings of Akbar's and later reigns—the seventeenth century and the latter half of the sixteenth—the red sandstone is very largely used. There are buildings of earlier date, now six and seven centuries old, in which this stone, frequently bearing Arabic inscriptions in raised letters, is still sharp-edged and fresh. It contrasts very favorably in this respect with many buildings in England sadly defaced by weathering of the sandstone. Oxford, perhaps, looks more venerable where the edges of the stone are worn and rounded, and the form of the moulding lost; but it would have been better if this had not happened. There are buildings in this country of a sandstone much resembling in color and general appearance that of the Moghul works in Northern India, but very different in durability. The exposed masonry of the Church of St. Michael, at Coventry, is seriously worn away, and seems to be crumbling continuously now. In past days, endeavor had been made to hold together with iron straps parts that were in danger of separating, and in some of these places little more than the iron strap now remains.

In the Indian buildings in which both white marble and red sandstone are used, the contrast of color is sometimes given by the use of the different materials for different parts of the building, sometimes by using them together, in alternate bands, or otherwise combined. Color is likewise shown in the Mohammedan buildings by inlaid work in the piers of the arcades, the spandrels of the arches, and other parts, and by lines of black marble inlaid in the white. The inlaid work is executed on a large scale in some buildings. The stones chiefly used are bloodstone, carnelian and agates. The inlaid work, besides that on the borders of panels and elsewhere in geometric figures, is chiefly representations of flowers in conventional style, and often with much freedom from the rigid symmetry which prevails in most Oriental designs. Inscriptions in the Persian or Arabic characters are either inlaid or carved in raised letters, not engraved like our inscriptions. In the interior of the great reception-halls of imperial buildings, and the more ornate private apartments, gilding also was much used. But some of the most beautiful of these Mohammedan buildings are those in which there is least color or applied decoration of any kind, so elegant are the forms and so just the proportions of the several parts, so refined the mouldings, and so true the execution. One other kind of ornamental work of much beauty is especially to be observed in these buildings, the stone screen-work of open tracery—large thin slabs of marble or sandstone, pierced with geometric figures of great variety. Very good specimens of this kind of work are to be seen in the Indian section of the South Kensington Museum.

The comparatively small variety of color thinly applied on the outside of the Táj Mahal at Agra—the Indian building perhaps best known in England—is the cause of its having frequently been felt,

at first sight, to be heavy. It is not really unrelieved by variety. Besides some inlaid colored work, it has straight lines of black marble inlaid, black zigzag lines on the thin engaged pillars at the corners, inlaid ornament following the outline of the parapets, and encircling the neck of the dome, and inlaid inscriptions in large letters. But so immense is the mass of white marble, that the relief thus afforded is comparatively small. A little study of the building reconciles the spectator to this massiveness, and only leaves him full of wonder and delight with the beauty as well as grandeur of the building. Its surroundings are on a scale of corresponding magnificence. The great square inclosure, with its splendid gateway, and the minarets at the corners; the straight-lined garden and its broad masonry channels, with shallow stream of water and rows of fountains in the middle; the sombre lines of tall dark cypresses, with trees of more varied foliage and color throughout the garden;—it is with these things about it, and a sense of great stillness and solemnity over the whole, that we look at this magnificent marble tomb. And we feel how large a measure of respect and gratitude is due to the men who did all this, to those who purposed and devised a monument on this scale of grandeur, and those who executed it in a manner worthy of the conception. Have not we reason to be glad that the wealth of building-power in those days threw itself into forts and palaces, mosques and tombs, pleasure-gardens for princes, and serais for travelers? What should we not have lost if Shah Jahán, for instance, had been a prince of smaller and more modest aims, and had bestowed the best efforts of his architects on jails and court-houses, town-halls and barracks, hospitals and schools? Their time has come. But it is better for art that Shah Jahán had his turn at something else. The world has gained.

If defect of color enhances the noble massiveness of the *Táj*, we feel this to be in agreement with the nature and purpose of the building. The use of color on Moghul buildings was well understood and very general. In the beautiful and wonderful city at the head of the Adriatic, which so many travelers to and from India have now-a-days an opportunity of seeing, we find a large amount of coloring of buildings, most of it very Oriental in character. But India has nothing to show of exactly the same kind. Buildings of brick, in India, if not faced with stone, were thickly plastered, and the coloring was given by figured designs, not whole surfaces of color, or by a facing of glazed work, which is of two kinds, on pottery and on plaster.

The use of glazed tiles and glazed plaster seems in India to be most frequent in the western frontier provinces of Sinde and the Punjab. But there are many good specimens at Gwalior, Delhi, and elsewhere, of buildings thus colored. The work goes by the general name of *Kashi*. Glazed tiles are used when a large surface is to be uniformly colored. Patterns also of different colors are given on single tiles. The glazing on plaster is used for colored devices, made up of separate small pieces, of the different colors, and these are laid on and cemented on the surface of the building. The plaster, which is made of lime and sand, receives first a very thin coating of glass containing lead, which both gives a fair smooth surface for the colored glazing that is to be afterwards applied, and enables it to adhere. Both these arts seem to have been imported from Persia. The earliest specimens of glazed-tile work known are at Mashad and Tabriz. The name Green Dome (*Sabz Gumbaz*) which is given to a conspicuous building at Mashad, of which the city is proud, is also borne by a tomb at Lahore, of which the green covering of the dome is in good preservation. Another at Lahore is similarly called Blue Dome (*Lila Gumbaz*). The cities of Moultan in the Punjab, and Tatta, and Hyderabad in Sinde, and others, have good specimens of this kind of work, as well as of the plaster *Kashi* work used for wall decorations and inscriptions. Lahore has many of great excellence and beauty; the most complete is the mosque of Wazir Khan, in the heart of the city. The figured tile work is now carried on in Sinde, at Tatta, on the Indus, and at Hala, 30 miles north of Hyderabad. The Masjid, built by Shah Jahán, at Tatta, has had the deficient tile work lately restored. At this place there is no glazed work of the other kind—that is, on inlaid pieces of plaster.

Indian brickwork, except in wells, is rarely seen, for it is always covered, or meant to be covered in one of these ways. Its quality is excellent, though its appearance is coarse, as it was not meant to be seen. Well-burnt bricks are united by well-made but rough mortar, the mortar courses being of great thickness, often much thicker than the bricks, giving the work the appearance almost of a concrete wall with thin bands of red brick. It is indeed a concrete. A similar material is used for terraced floors and roofs. And there are cases where—the wood and tiles on which it was laid having decayed and fallen away—the terrace covering has remained, spanning the gap, as a single block of artificial stone or concrete bridge.

In stone buildings in various parts of the hill countries of India, the insertion of horizontal beams at intervals in the masonry, which is a common constructive arrangement, gives a pleasing variety to the outer face of the work, like the use of stone of different colors. The practice is similar to the use of bonding courses of red brickwork, which we see in Roman walls of stone masonry in Britain. This was well shown in the old wall lately discovered in extending the railway buildings in the neighborhood of Fenchurch-street Station. The bright red bands were of tiles or bricks of large size, of which there were three courses in each horizontal band. Similar bonding brickwork of bright color is to be seen in a massive Roman wall at Leicester; of which English builders have taken advantage in a very practical way, by using part of the materials, both brick and stone, for the adjoining church of St. Nicholas. In the church the construction is repeated, stone masonry with courses of brick at intervals. The cathedral of Carlisle has in like manner helped itself to stone from a neighboring Roman wall.

In these cases, as in many others, perhaps no great harm was done, as the walls were plain and uniform masses of solid masonry, interesting chiefly on account of their history and their construction, and having plenty of the work still left to satisfy this interest. But the practice is a dangerous one. It has been often followed, in all countries, and has sometimes not been quite so harmless. We cannot tell now what we have lost at old Delhi. Bernier says, Shah Jahán's new city, which was being built when he was there, was conveniently near the old one, which supplied quantities of building material ready for use. Very likely the honest intention in the first place was to take only the stones from absolute ruins. But we know how difficult it is to get any rule of this kind rigidly adhered to, and to prevent the despoiling of buildings which, if in a sense ruins, are yet ruins to be carefully and tenderly preserved.

OBSERVATIONS ON THE MOVEMENT OF WATER IN STREAMS.

By P. GRAEVE.

Translated from Civilingenieur for Abstracts of Institution of Civil Engineers.

THE law of the movement of water in streams is still imperfectly known, partly in consequence of the complicated character of the motion, and partly because observations have been made with imperfect instruments.

Some observations by the author on the Oder and Warthe are first given. A Woltmann's current meter was used, the curve of revolutions of which had been already very carefully determined. Velocity observations were taken at 5 meter (16.4 feet) distances horizontally, and at 0.2 meter (8 inches) distances vertically, from 0.1 (4 inches) below the surface to 0.25 meter (9.8 inches) from the bottom. Altogether two thousand five hundred observations were made. The results were as follows:

	Discharge.	Mean Velocity.
	Cubic meters. (35.316 cubic ft.)	Met. per sec'd. (3.28 ft.)
Oder, above mouth of the Warthe.........	155.4	0.73
Warthe...	185.7	0.917
Oder, below junction of Warthe..........	336.0	0.712

The curves of velocity in each vertical are given for the three river sections at which the observations were made. These curves are so irregular that very little can be inferred from them immediately as to the law of diminution of velocity with increase of depth. In all the velocity diminishes more rapidly in the lower than in the upper part. The sudden diminution very near the bottom may perhaps be due to the silt in the water. Mean curves were then constructed by combining observations at corresponding heights. The mean curves were found to be much more regular than the single curves, so that the large irregularities of the latter neutralize each other. The curves confirmed the conclusion of Hagen, that in broad streams the greatest velocity is at the surface, unless accidental causes reduce the surface velocity. The curves agreed nearly with a parabola having a horizontal axis at the water surface, and not so well with a parabola having a vertical axis and the vertex at the river bed. The mean velocity deduced from the parabolic curves is a little less than that of the corresponding mean curves. For the parabola with horizontal axis at the water surface, the mean velocity is found at 0.5773 of the depth; and for the parabola with vertical axis, at 0.5555 of the depth. Taking the velocities from the four mean curves at these depths and comparing them with the actual mean velocities, it is found that the agreement is closer at 0.5773 of the depth than at 0.5555; but in neither case is the difference from the mean very sensible. The ratio of the surface and mean, and surface and bottom velocity, is then examined. These ratios vary, not only for different inclinations and different water depths, but also for the same inclination and different depths of stream. Hence the mean velocity can be inferred from the surface velocity observed by floats only with approximate safety. Horizontal curves of surface and mean velocity are then examined. These do not confirm the conclusion of some haudraulicians, that the curves of horizontal velocity are parabolas. Nor does the form of the curves agree well with that of the bed.

The observed mean velocity of the Oder and Warthe is then compared with the velocity calculated by various formulæ. The following summary shows the results:

	Warthe.	Oder, below Junction of Warthe.
	Meter per second.	Meter per second.
Observed mean velocity.	0.917	0.7113
Humphreys' and Abbot's formula	0.98307	0.9452
Grebenau's formula	0.975	0.962
Bazin's formula	0.847	0.763
Gaukler's formula	1.3061	1.0515
Bornemann's formula	0.0037	0.00055
Hagen's formula (old)	0.904	0.89
" " (new)	0.941	0.916
Ganguillet and Kutter's formula	0.727	0.629

It may be concluded that the most complicated formulæ, such as those of Humphreys and Ganguillet, are not in all cases more trustworthy than the simplest, such as Hagen's and Bazin's. It is doubtful if any formula is applicable in all cases; and it appears that Hagen has taken the right path in adopting two different expressions for small streams and more important rivers.

A HEAVY gun, believed to be one of the oldest pieces of ordnance in existence, has been sent home by the Governor of Cyprus, for the Museum of Artillery at Woolwich. It is of cast iron, and weighs 25 cwt. The manufacture is probably Venetian, and the ancient weapon is well shaped, in the form of a cup or goblet, the mouth being wide and deep, to hold a large stone shot, while the narrower pedestal is hollowed to receive the powder charge. A round stone, weighing about 6 cwt., has been sent with the gun, and it is suggested that this is the kind of missile fired from it, as proved to have been the case with similar guns in England. One which it somewhat resembles is already in the Rotunda at Woolwich, having been found in the moat at Bodiham Abbey, and specimens of the stone cannon balls are already in that museum. The gun from Cyprus is in much better preservation. The cup or mortar is 19in. deep and 18in. across, and the external diameter is 26in., which allows 4in. for thickness of metal. The powder chamber, 7in. across, extends some 30in in a tunnel, behind the mortar, and terminates in a vent or touchhole going off at right angles, and fully an inch in diameter.

THE STRONGEST OF THE BRONZES.

A NEWLY DISCOVERED ALLOY OF MAXIMUM STRENGTH.

By ROBERT H. THURSTON.

Transactions of American Society of Civil Engineers.

THE writer, when conducting a series of investigations of the properties of the copper-tin-zinc alloys, in the Mechanical Laboratory of the Stevens Institute of Technology, by request of a committee of the U. S. Board, organized under an act of Congress secured by a request of the American Society of Civil Engineers, and of gentlemen taking an interest in that enterprise, was led to devise a method of planning that research* and a system of recording data that has since led to the discovery of alloys of probably the maximum possible strength obtainable by any combination of the elements studied.

This system is briefly the following:

In any triangle, B, C, D, Fig. 1, let

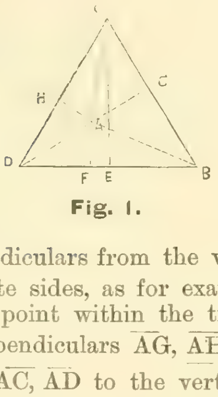


Fig. 1.

fall perpendiculars from the vertices to the opposite sides, as for example, $\overline{CE}$. From any point within the triangle, A, let fall perpendiculars $\overline{AG}$, $\overline{AH}$, $\overline{AF}$, and draw $\overline{AB}$, $\overline{AC}$, $\overline{AD}$ to the vertices, thus obtaining three triangles, $\overline{ABD}$, $\overline{ABC}$, ACD; their sum is equal to the area of the whole figure BCD.

Now we have, since the triangle is isoceles, and

$$\frac{\overline{CE}\times\overline{BD}}{2}=\frac{\overline{AF}\times\overline{BD}}{2}+\frac{\overline{AG}\times\overline{BC}}{2}+\frac{\overline{AH}\times\overline{CD}}{2},$$

$$\overline{CE}\times\overline{BD}=(\overline{AF}+\overline{AG}+\overline{AH})\times\text{BD};$$

and

$$\overline{CE}=\overline{AF}+\overline{AG}+\overline{AH}$$

which follows wherever the point A may be situated; it is true for every point in the whole area $\overline{BCD}$. Assuming the vertical $\overline{CE}$ to be divided into 100 parts; then

$$\overline{AF}+\overline{AH}+\overline{AG}=100 \text{ and } \frac{\overline{AF}}{100}, \frac{\overline{AH}}{100}, \frac{\overline{AG}}{100}$$

measures the relation of each of the altitudes of the small triangles to that of the large one.

But we may now conceive the large triangle to represent a triple alloy, of which the areas of the small triangles shall each measure the proportion in which one of the constituents enters the compound, and

$$\overline{BCD}=100\text{ per cent.}=\left(\frac{\overline{AF}}{100}+\frac{\overline{AG}}{100}+\frac{\overline{AH}}{100}\right)$$

BD, or $\overline{CE}=100$ per cent. $=\overline{AF}+\overline{AG}+$ AH per cent. and the altitude of each small triangle measures the percentage of some one of the three elements which enter that alloy which is identified by the point. Thus every possible alloy is represented by some one point in the triangle BCD, and every point represents and identifies a single alloy, and only that. The vertices B, C, D, in the case to be here considered, represent respectively, copper=100, tin=100, zinc=100. Thus, having determined a method of studying all possible combinations, the writer next prepared to examine this field of work in the most efficient and complete manner possible, with a view to determining, by the study of a limited number of all possible copper-tin-zinc alloys, the properties of all the numberless, the infinite, combinations that might be made, and with the hope of detecting some law of variation of their valuable qualities with variation of composition, and thus ascertaining which were the most valuable for practical purposes.

With this object in view, the triangle laid down to represent this research, was laid off into concentric triangles, Fig. 2,

* On a new method of planning researches, &c., by R. H. Thurston, Proc. Assoc. for Advancement of Science. Vol. XXVI.

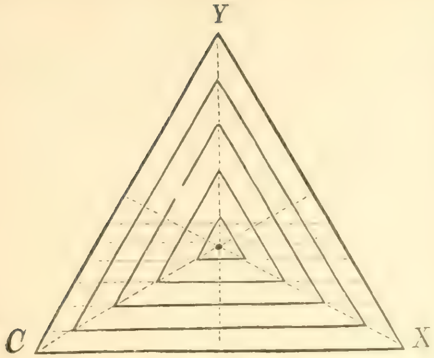


Fig. 2.

varying in altitude by an equal amount—10 per cent.—on which were laid out the following series of alloys:

COPPER-TIN-ZINC ALLOYS.—THURSTON.

Copper.	Zinc.	Tin.	Copper.	Zinc.	Tin.
10	10	80	30	40	30
10	20	70	30	50	20
10	30	60	30	60	10
10	40	50	40	10	50
10	50	40	40	20	40
10	60	30	40	30	30
10	70	20	40	40	20
10	80	10	40	50	10
20	10	70	50	10	40
20	20	60	50	20	30
20	30	50	50	30	20
20	40	40	50	40	10
20	50	30	60	10	30
20	60	20	60	20	20
20	70	10	60	30	10
30	10	60	70	10	20
30	20	50	70	20	10
30	30	40	80	10	10

These alloys were first all tested in the Autographic Recording Machine, and their strain diagrams were carefully studied It was at once found that only a very few were of great value, and that the alloys represented by that part of the field lying on the tin-zinc side of a line running from copper = 70, tin = 30, zinc = 0, to the point copper=40, zinc=60, tin=0, were too soft or too brittle and weak to be of value. The research was now restricted to the examination of alloys lying nearer the point copper = 100, *i. e.*, the upper vertex of the triangle as seen in the figure, and all such alloys were tested by tension, compression and torsion, and by transverse stress.

The results were quite accordant, and the quality of the metal could be judged as well by one set of data as by another, although, as a matter of course, the strain diagram, obtained automatically, gave the best idea of the nature of the metal where the observer had been accustomed to that method. When the figures thus obtained had been entered on the triangular map, lines of equal strength, of equal ductility, or of equal resistance could be drawn, as in topographical work lines of equal altitude are drawn, and the map became thus a useful representation of the valuable qualities of all possible alloys.

Figure 3 represents such a map* of all copper-tin-zinc alloys. The scale of altitudes is obtained by considering the relation of tension to torsion resistance as 25,000 pounds per square inch (1,758 kilograms per square centimeter) for each 100 foot-pounds. (13.82 kilogrammeters) of torsional moment for the standard test specimen, which specimen was turned to a standard gauge, and made ⅝ inch (1.84 cm.) diameter and 1 inch (2.54 cm.) long in the cylindrical part exposed to strain.

These facts, as determined experimentally, were subsequently still better exhibited by another method devised by the writer for class illustration; thus:

Upon a triangular metal base, laid off as above, erect a light metallic staff by drilling a hole for its support at each point laid down as representative of an alloy tested; make the altitude of each of these wires proportional to the strength of that alloy. There is thus produced a forest of wires, the tops of which are at elevations above the base plane proportional to the strengths of the alloys studied. Similar constructions may be made to represent the elasticity, the ductility, or any other property of all these alloys.

Next fill in between these verticals with clay or, better, with plaster, and carefully mould it until the tops of all the wires are just visible, shining points in the now smooth surface of the model. The surface thus formed will have a topography characteristic of the alloys examined, and its undulations will represent the characteristic variations of

* Reports U. S. Board testing Iron, Steel, &c. Washington. 1878—1881.

quality with changing proportions of the three constituents.

This was made for the writer, and was cast in an alloy which is the subject of this paper, the plaster cast made as above being used as a pattern, and this cast is used in lecture-room illustration, and is in a later and more complete study of this important and intensely interesting field of investigation; the plan was never completely carried out, in consequence of the failure of Congress to make needed appropriations and the consequent demise of the Board.* These

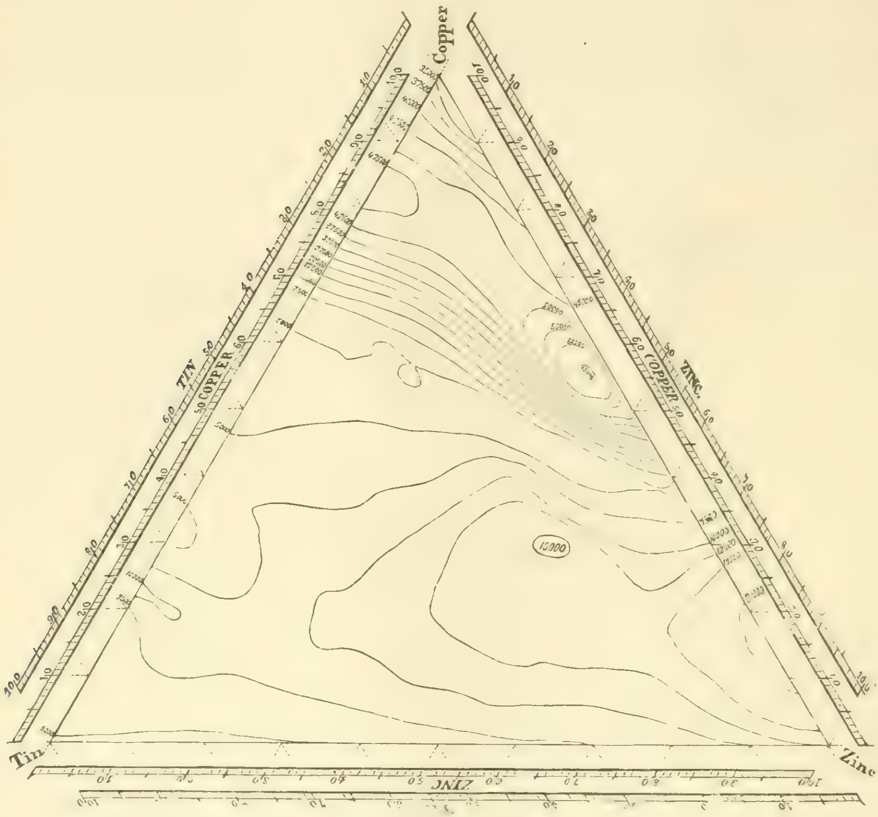


Fig. 3.

supplied where demanded to other institutions.

Figure 4 is a good representation made from a photograph of the model for the American Association for the Advancement of Science.*

The remarkable variations of quality here so strikingly shown, naturally attracted the attention of the writer, as of every one to whom he exhibited these models and maps, and a further investigation was made.

The alloys studied were orignally intended to furnish data during a preliminary research that should serve as a guide alloys were purposely made precisely as the brass founder is accustomed to make them, without other precautions than those observed by every good founder, and without using any of the deoxidizing fluxes—as phosphorus—that would have been experimented with later. The intention was to make this first survey of the field rapidly, inexpensively, and in such a manner as to give a good idea of the best way to pursue the later and much more exact research, while giving the founder a good idea of the nature of

* Proceedings, 1878, Vol. XXVI.

* An effort which has been recently made to re-establish the Board has not yet (December, 1880,) met with success.

the metals that he turns out in every day work.

The data obtained were consequently exceedingly variable, and the results of this work indicated as one, and not the least valuable, of deductions from it that the same alloy, and especially where the proportion of copper is great, may give very different figures when tested according as it is more or less affected by the many circumstances that influence the value of all brass-foundry products.

line marked 65,000 pounds per square inch (4,570 kilogs. per sq. cm.) tenacity, and is represented on the model, Figure 4, by the peak of the mountain seen at the farthest side—the copper-zinc side as drawn.

This is obviously the strongest of all bronzes, and an alloy of this composition, if exactly proportioned, well melted, perfectly fluxed, and so poured as to produce sound and pure metallic alloy, with such prompt cooling as shall prevent

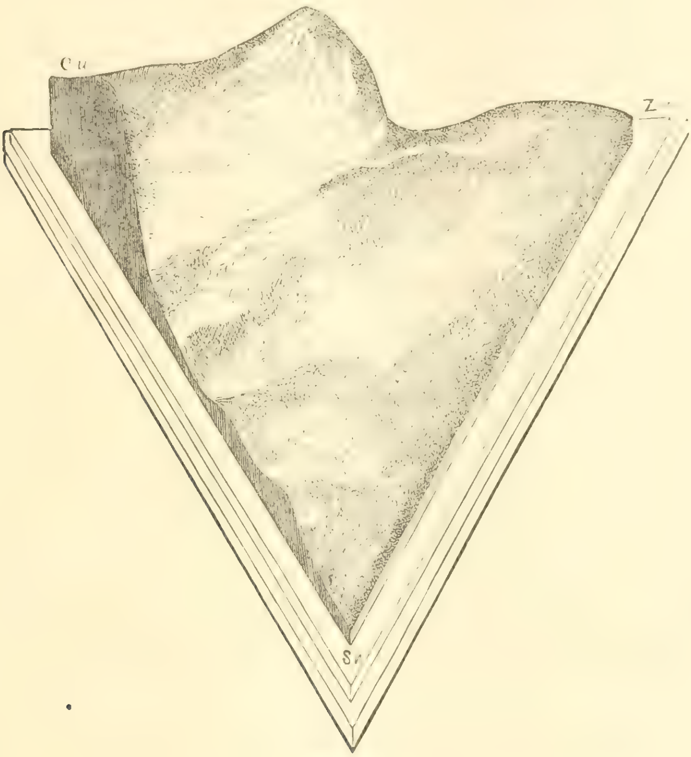


Fig. 4.

Some of the variations in the model are probably due to such accidental circumstances, and quality shown by any individual alloy is representative of a mean which the writer was often compelled to deduce from observations which were quite discrepant. But allowing for all such minor variations, it is evident at a glance that the alloys of maximum strength are grouped, as shown in Figures 3 and 4, about a point not far from copper=55, zinc=43, tin=2. This point is encircled in the map, Figure 3, by the

liquation, is the strongest bronze that man can make.

The writer finally made this alloy, and of it constructed the model represented in the last figure. It is a close-grained alloy of rich color, fine surface, and takes a good polish. It oxidizes with difficulty, and the surface then takes on a pleasant shade of statuary bronze green. Testing it, it was found to have considerable hardness, but moderate ductility, though tough and ductile enough for most purposes; it would

forge if handled skillfully and carefully and not too long or too highly heated, had immense strength, and seemed unusually well adapted for general use as a working quality of bronze. In composition, however, it is seen to be a brass, with a small dose of tin.

The alloy made as representing the best alloy for purposes demanding toughness as well as strength contains less tin than the above composition. Cu., 55; Sn., 0.5; Zn., 44.5.

It had a tenacity of 68,900 pounds per square inch (4,841 kilogs. per sq. cm.) of original section, and 92,136 pounds (6,477 kilogs.) on fractured area, and elongated 47 to 51 per cent., with a reduction to from 0.69 to 0.73 of its original diameter.

No exaltation of the normal elastic limit was observable during tests made for the purpose of measuring it if noted. This alloy was wonderfully homogeneous, two tests by tension giving exactly the same figure 68,900. The fractured surface was in color pinkish yellow, and was dotted with minute crystals of alloy produced by cooling too slowly. The shavings produced by the turning tool were curled closely, like those of good iron, and were tough and strong.

The strain diagrams from the autographic machine are shown in *fac simile* and two-thirds of full size in the accompanying Plate 1. Their tenacity, as estimated from their resistance to torsion, is nearly equal to that determined by direct experiment, and the four samples tested 1,001 A, B, C, D, have given strain diagrams that are all nearly precisely alike. They exhibit an elastic limit, *e*, at about two-fifths their ultimate resistance, and just about the same as a piece of excellent gun bronze (Cu. 90; Sn. 10 per cent.), 1,252 A, the strain diagram of which lies beside them in dotted line. Their elastic resistance, which is measured by the area of the curve up to *e*, is superior to that of the gun bronze, and their elastic range is seen to be greater on inspection of the "elasticity lines," *ê ê*. In ductility they excel 1,252 A, but not greatly, as is seen by comparing 1,001 A with 1,252 A. Their toughness is shown by the great area and the altitude of the curve; their excellence of quality is also shown by its smoothness of outline. The homogeneousness of structure is exhibited by the similarity of the diagrams and by the smoothness of the bend at *e*, which marks the elastic limit.

At *f* is a depression of the normal line of elastic limits produced by 17 hours intermission of distortion under the load there carried. This slight depression marks this alloy as one of the "tin class."

Diagram 1252 B is given by a very fine gun bronze; 1001 *x* is an hypothetical diagram, such as would be produced were the alloy here described so carefully fluxed and cast as to exceed in strength the unfluxed alloys actually tested, 1001 A, B, C, D in as great a proportion as 1252 B excels 1252 A. The diagram 1001 *y* would be produced were it possible to so far improve this alloy as to cause it to excel 1252 A as greatly as No. 1001 actually did excel the gun bronze made under similar conditions in this preliminary rough work. No. 1004 A is copied to exhibit the immense superiority of the alloy 1001 to one but little removed from it and which is considered by some brass founders an excellent composition.

It is impossible to say, without direct test, to what extent the alloys shown in figures 3 and 4 may be improved by special methods of working, and by more perfect fluxing than is usually secured in the foundry. This was to have been the subject of the next investigation; the ground had been cleared and the valuable alloys identified, and the work planned could have been rapidly and satisfactorily done had the opportunity been allowed. But from what can be gathered by the experience acquired the writer is inclined to suppose that careful mixture, thorough fluxing with phosphorus or other deoxidizing element, casting under pressure, rapidly cooling, and finally cold rolling or cold pressing as practiced by Dean,* copper-tin-zinc alloys, containing not to exceed $z+3t=30$ per cent. could be given a strength exceeding by 50 per cent. that obtainable under the ordinary conditions met with in the brass foundry. During the writer's experiments the copper used had a tenacity, as cast in small bars, of but one-half that obtained by Mallett, who fluxed out the

* On the Mechanical Treatment of Metals; by R. H. Thurston; Metallurgical Review, 1877.

oxygen more completely. Similarly, in these preliminary trials, gun bronze broke at two-thirds the figure obtained frequently in making ordnance.

Alloys rich in copper receive most benefit by such special treatment.

The writer has found that ordinary bronze, composed of copper and tin, may be taken with rough approximation to accuracy as having a tenacity, as cast in the ordinary course of a brass founder's business, of about—

$$T_c = 30{,}000 + 1{,}000\,t;$$

where t is the percentage of tin, and not above 15 per cent. Thus gun bronze can be given about $30{,}000 + (1{,}000 \times 10) = 40{,}000$ pounds per square inch, if well made. In metric measures

$$T_{c^1} = 2{,}109 + 70.3\,t,$$

giving for good gun metal $2\,109 \times 703 = 2\,812$ kgs. per sq. cm.

For brass (copper and zinc) the tenacity may be taken as

$$T_z = 30{,}000 + 500\,z;$$

where the zinc is not above 50 per cent.; and

$$T_{z^1} = 2{,}109 + 35.15\,z.$$

Thus copper 70, zinc 30, should have a strength of $30{,}000 + (500 \times 30) = 45{,}000$ pounds per square inch, or $2{,}109 + (35.15 \times 30) = 3{,}165$ kilogrammes per square centimeter.

Referring once more to Figures 3 and 4, it is seen that a line of maximum elevation crosses the field marking the crest of the mountain in Figure 4, of which the "maximum bronze" is the peak. This line of valuable alloys may be practically covered by the formula:

$$M = z + 3t = \text{Constant} = 55,$$

in which z is the percentage of zinc, and t that of tin. Thus a maximum is found at about $t = 0$, $z = 55$, while the other end of the line is $z = 0$, $t = 18$.

Along this line the strength of any alloy should be at least

$$T_m = 40{,}000 + 500\,z.$$
$$T_{^1m} = 2{,}812 + 35.15\,z.$$

Thus the alloy $z = 1$, $t = 18$ will also contain copper $= 100 - 19 = 81$ and this alloy cu. 81, zn. 1, sn. 18 should have a tenacity of at least

$$T_m = 40{,}000 + (500 \times 1) = 40{,}500 \text{ lbs. per sq. in.}$$

$$T_{1m} = 2{,}812 + (35.15 \times 1) = 2{,}847 \text{ kgs. per sq. cm.}$$

The alloy: cu. 60; zn. 5; sn. 16; should have at least the strength

$$T_m = 40{,}000 + (500 \times 5) = 42{,}500 \text{ lbs. per sq. in.}$$

$$T_{1m} = 2{,}812 + (35.15 \times 5) = 2{,}988 \text{ kgs. per sq. cm.}$$

while the alloy z, 50; sn, 2; cn, 48; should give, as a minimum specification:

$$T_m = 40{,}000 + (500 \times 50) = 65{,}000 \text{ lbs. per sq. in.}$$

$$T_{1m} = 2{,}812 + (35.15 \times 50) = 4{,}570 \text{ kgs. per sq. cm.}$$

These are rough working formulas that, while often departed from in fact, and while purely empirical, may prove of real value in framing specifications. The formula for the value of T_m fails with alloys containing less than 1 *per cent. tin* as the strength then rapidly falls to $t = 0$.

The improvement that may be expected to follow special treatment of some, and probably nearly all the more valuable of these alloys, may be inferred from the fact that Mr. S. B. Dean, in 1869,* increased the tenacity of cast gun bronze from 27,230 to 41,471 pounds per square inch (1,915 to 2,915 kilogs. per sq. cm.) by cold working, and General Uchatius, who introduced the Dean process in Austria, by chilling, increased the strength of his "steel bronze" from 35 092 pounds per square inch (2,260 kilogs. per sq. cm.), to 43,310 pounds (3,050 kilogs.);† the elastic limit remaining, however, unchanged at 5,680 pounds per square inch (400 kgs. per sq. cm). This metal then cold rolled by the Lauth method of Jones & Laughlin's, rose in tenacity to 71,937 lbs. with an elastic limit at 24,140 (5,066 and 1,700 kilogs. per sq. centimeter). This was the regulation alloy: copper, 90; tin, 10. When the tin was increased to 12 per cent. the alloy was too hard to roll.

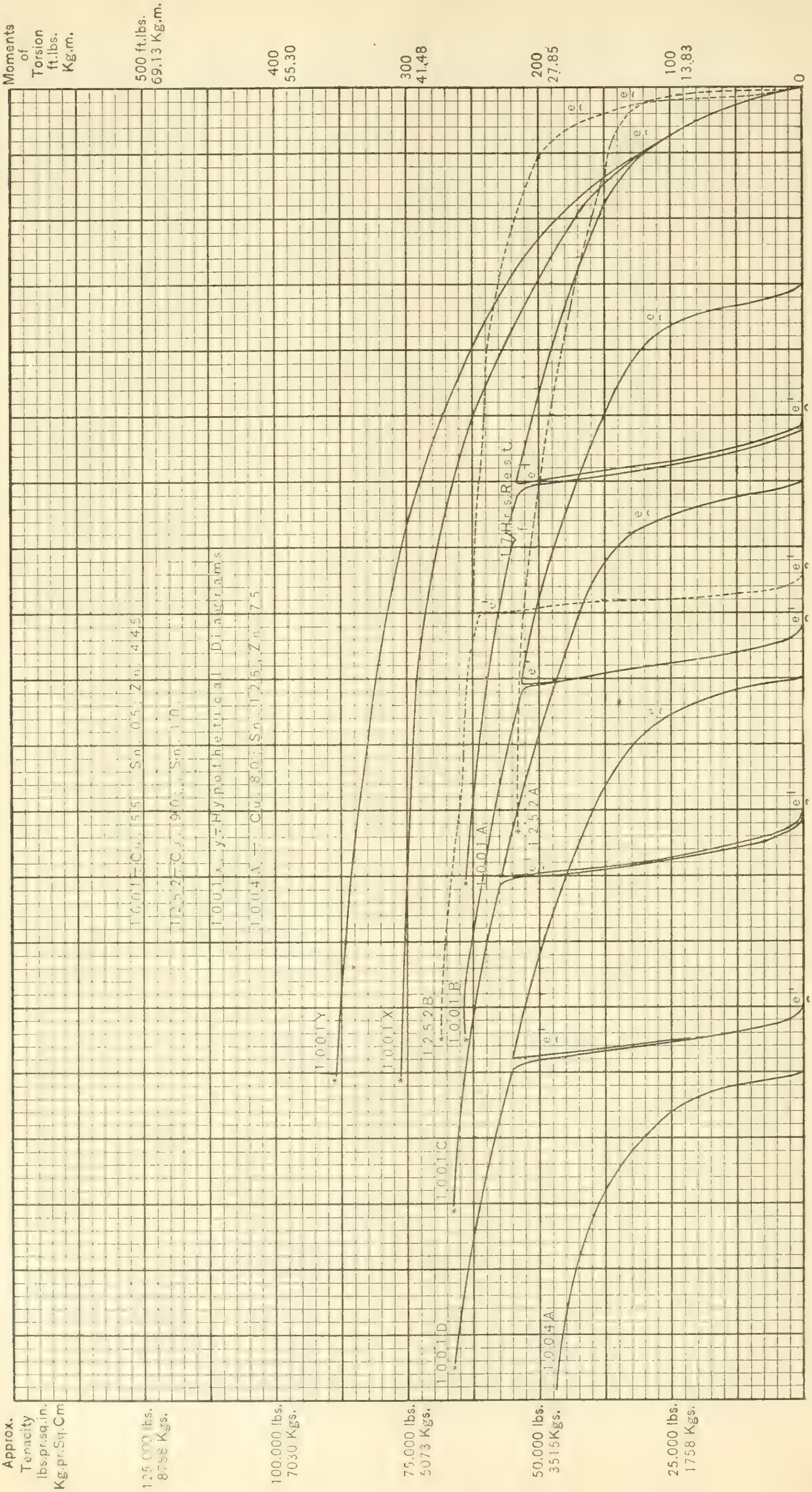
Colonel Rosset, of the Italian army, repeated Dean's work and extended it with the same result.‡

On the copper side of the maximum point on our map and model of the copper-tin-zinc alloys, is one that has been well studied and is of remarkable value. This metal was discovered by Mr. J. A.

* Ordnance Notes, No. XL, p. 255.

† Report on Manufactures and Machinery at Vienna, 1873; R. H. Thurston: p. 326.

‡ Resistenza dei Principali Metalli; Torino; 1874.


Moments of Torsion ft.lbs. Kg.m.
500 ft.lbs. 69.13 Kg.m.
400 55.30
300 41.48
200 27.85
100 13.83
0
Approx. Tenacity lbs.pr.sq.in. Kg.pr.Sq.Cm
100,000 lbs. 7030 Kgs.
75,000 lbs.
50,000 lbs. 3515Kgs.
25,000 lbs. 1758 Kgs.
17Hrs Rest
1.001Y
1.001X
1.252B
1.001B
1.001C
1.001D
1.004A
1.001A
1.252A

Tobin (U. S. Naval Engineer Corps), and described to the writer several years ago.* It consists of copper, 58.22; tin, 2.30; zinc, 39.48; it is hardly as strong as the alloy already described, but as cast had a tenacity of 66,500 pounds per square inch of original section, and 71,378 per square inch of fractured area (4,575 and 5,019 kilograms per sq. cm.) at one end of the bar which was, as usual, cast on end, and 2 per cent. more at the other. This alloy, like the maximum metal, was capable of being forged or rolled at a low red heat or worked cold. Rolled hot its tenacity rose ot 79,000 pounds (5,553 kgs. pr. sq. cm.), and when moderately and carefully cold rolled, to 104,000 pounds (7,311 kgs). It could be bent double either hot or cold, and was found to make excellent bolts and nuts.

A large proportion of the alloys on the copper side of the series marking the line $z+4t=50$ may be treated with equal or greater success, and there should be no trouble in securing copper-tin-zinc alloys of tenacities between 75,000 and 100,000 pounds per square inch (5,273 to 7,030 kilogs. per sq. cm.), by intelligent and skillful working. As I have elsewhere stated,* the metals used should be perfectly pure (Lake Superior copper; Banca or Australia tin; and New Jersey zinc); they should be protected from oxidation when fusing, carefully fluxed with phosphorus or other good deoxidizer, poured quickly into chills, cooled with the utmost rapidity, and the castings, when possible and safe so to work, rolled or forged either cold or hot. Should the work of the U. S. Board to Test Metals ever be resumed, this is likely to prove one of the most important and profitable lines of investigation. The results here given, it is obvious, are subject to revision after more work has been done, and the revision of data already obtained, the exclusion of unreliable and invaluable observations, and the formulation of more precise deductions will furnish employment for future investigators.

HOUSE ARCHITECTURE—PAST AND FUTURE.

From "The Builder."

When the late M. Viollet-le-Duc's work on the "Habitations of Men in all Ages" appeared, while no one could question the charm and suggestiveness of the book, it was regarded, and not unjustly, as including a good deal too much of the element of romance for a professedly historical sketch. The distinguished author might have been accused, in the words of Sheridan's great Parliamentary *bon-mot*, of having been, to some extent, "indebted to his imagination for his facts;" a criticism which, however true from the practical point of view, might with some readers have been rather a recommendation than the reverse. It was something new and unsual, at all events, to be asked to consider the history of the human habitation as a whole, apart from the mere practical view of it as a necessity of every-day life. There are many ways of regarding the house, and most of them, it must be confessed, are prosaic. There is the picturesque architect's point of view, which is the least prosaic, which, indeed, is sometimes so little prosaic as to fall into the opposite condemnation of being unpractical. There is the contractor's point of view of it, as a piece of construction out of which to make money. There is the sanitarian, who regards it as a place liable to develop smells and gases; and the investor of money, who regards the house as property worth so many years' purchase. And none of these ways of regarding the habitation are very exciting to the imagination. But take the subject at large and as a whole, and how interesting and picturesque it becomes. What a number of pictures arise in the mind, what a multitude of associations, all connected with and arising out of the one fact that mankind have required buildings to shelter them.

We look around in imagination on the various shapes which dwellings take in

* By letter dated Feb. 6th, 1876, and verbally in 1875.

* Metallurgical Review, 1877; Mechanical Treatment of Metals.

various parts of the world at the present day; all have their own significance—one had almost said their own picturesque value. In regard to the latter point there are certainly deductions to be made, when we think of the rows of brick walls in some of our towns; the three or four lines of oblong windows in the larger houses, and the "damnable iteration" of bay windows in the smaller class of street residences. Possibly we possess, in England, specimens of about the most uninteresting forms which the human habitation has ever assumed; at all events, we can hardly be outdone in this way. There has been a great deal of fine, stately, or picturesque and pretty house building on this island; but when our houses are dull looking and grimy, they are thoroughly so. It may be that, if we could only recognize it, there is, after all, a suitability to the circumstances, an occult fitness of things, even in the speculating builder's street house. It may be the true expression of the circumstances of the life that is lived in it—most dwellings are so in one way or another; but then how very unfit the fitness of things must be in that case.

> "Mist clogs the sunshine;
> Smoky dwarf houses
> Hem me round everywhere;
> A vague dejection
> Weighs down my soul."

So says a poet of the day, and well he may. But it may perhaps be asked whether the mean houses are a cause or consequence of the dejection; and there may be as much to be said for the one view as the other. Life under natural and healthy circumstances will make for itself dwellings that will have something cheerful, characteristic, picturesque, about them. Country cottages in England have such character, and Swiss châlets, and log houses, perhaps, in freshly-cleared "backwoods." But where life has become a kind of mill, grinding down to the same shape all that is put into it, then the houses take a kind of mill form, too—a mill architecture is developed.

Not a pleasant or romantic aspect of the habitation, this; but, fortunately, this modern development, which will obtrude itself when the subject is mentioned, forms only a single, and may, if the present and the next age do their duty, form only a short-lived phase of house building. We cannot say positively, perhaps, that long-remote ages, as in Egypt, may not have seen an equally dull and depressing form of habitation for the many. In days when great kingly and priestly castes held sway and built enormous temples and palaces, it is only too probable that the average house of the population at large was but mean. There could be little to spend on it where so much was spent on unremunerative structures of vast size and costliness. Probably, the earliest house of all (after the cave, ready made) was of the nature of a tent; something easily removable; and the tent-like form and tent-like frailty of structure would impress themselves on more stationary domestic architecture for long after. From the tent-like form the next step would be to the hut form: the radical distinction between the two being that between sloping sides and a pointed finish, and upright walls with a complete roof, the superiority of which, in convenience and airiness and finished appearance, over the tent form, would hardly allow any more standing room for the latter; and then, when the hut form is established, comes the curious and long-drawn-out action and reaction of house and temple architecture upon one another. For, give the hut a verandah or porch, a deep projection of the roof with posts to carry it, and there is the temple in embyro, to begin with. But the temple was not confined to mere utilitarianism as a structure. The house for the god might be on the model of the hut, but it must be durable, rich, magnificent in scale and decoration. More costly and ponderous materials must be employed for it, and higher skill in design must be developed and displayed, at whatever cost, and that as a sacred duty. We see the most portentous development of this glorified hut architecture in Egypt; and a very striking idea it gives us of the lapse of time occupied in the development of that wonderful Egyptian-temple architecture, when we think through what long stages this transformation must have gone by which the grand columned temple grew out of the hut suggestion. This was under the sway of a mighty superstition of the supernatural, which crushed the

mere house, the mere human habitation, out of sight. The wrecks of the temples are still sublime in their decay; but, for all trace of the dwellings of the people, they might as well not have existed. In Greece the temple was still the main object of architecture; that the Greeks may have had convenient houses is possible; that whatever houses they built would have been graceful and beautiful, wherever there was any excuse for spending wealth over them, seems certain. But, at any rate, the best of them were so inferior in scale and importance to the temples that the dust of time has covered them. That Athens and other important cities contained thousands of habitations is historically known; but that cannot have been an important house architecture in the main which has left so little trace behind it. But under the less superstitious and more practical as well as more wealthy Roman, the house takes its revenge on the temple. One of the first Cesars was decreed the right to form on the façade of his house a pediment, the special feature previously of the temples of the gods. But this one fact (as it is traditionally reported to have been) was only typical of the place which domestic as well as civil architecture was beginning to assume with the progress of Rome in wealth and luxury. The pilasters and columns of the temple became attributes of domestic and civil architecture; the house rose to architectural grandeur and significance. The small rooms of the elegant houses of Pompeii, the provincial town, are decorated with semi architectural embellishments, which are the old temple architecture filtered down to the level of drawing-room prettiness. Where the superstitious or reverential side of human nature is in abeyance, where the commercial and practical side comes uppermost, there the dwelling takes an important place as architecture. The mansion is a sign that æstheticism and love of pleasure, the enjoyment of this life, has elbowed out superstition and asceticism; the healthy culture of this world has taken the place of the mystical contemplation of another. The religious spirit is not favorable to the development of the habitation; "Let us eat and drink, for to-morrow we die," has been a sentiment much more favorable to the growth of luxury and beauty in private dwelling houses than any spirit of religious aspiration, which would rather write "Mene, mene," on the walls of the most gorgeous apartment. The history of Christian architecture illustrates this: In the first great uprising of Christian reform there was, indeed, little account made of architecture or art of any kind; even the religious edifice, at first, received notice of disestablishment; the Most High "dwelleth not in temples made with hands." But this elevation above all material aids to faith could not be sustained for long. The Christian soon brought back the grand features of columnar architecture to the service of the temple, and other influences moulded them to new architectural forms and expressions, till in the Mediæval period the great architecture of the day is again, as in Egypt and Greece, all concentrated in the religious edifices. The house has architecturally all but disappeared, except in the form of the castle, made strong and massive for purposes of rapine, not to show forth the amenities of life. Even as late as Shakespeare's time, the church is distinguished as "the holy edifice of stone," obviously in contrast to the houses, the ordinary dwellings of his day, although, of course, there were exceptions for the great. Then followed the Renaissance, bringing back "the kingdom of this world" in unmistakable fashion with all its "pomps and vanities," its luxury and taste, its costly, intellectual, refined self-indulgence, and again domestic architecture took a leading place; again the habitation borrowed and adapted the features of Classic temple architecture to grace and adorn itself, though with more refinement and taste, and a more just and thoughtful æsthetic application of the materials, than in the Roman days.

From the Renaissance period the house has never ceased to play an important part in the architecture of Europe—so far, at least, as concerns the dwellings of the wealthier class. During the Georgian period in this country it sank lowest in regard to architectural development, even more so than the generally low level of architectural art might have seemed to render inevitable; it ceased almost to be architecture in the usual sense of the word, though very likely

those who designed the house of that day thought that a symmetrical cube of building with a porch projecting from one side of it represented all the architecture that a sensible man need desire for his house. In the main, however, the Italian Renaissance mansion has impressed its mark on the better class house of modern Europe more than any other form of architecture. Even the Elizabethan house is a record of modification of the Renaissance house (we are speaking now of architectural style, not of plan), combining the refinement of Renaissance style with some of the picturesqueness of Gothic—a combination which the French château of the early Renaissance period displays in still better and more graceful and fanciful form. In spite of the taste for Gothic houses which accompanied the general movement in favor of Mediævalism, there has always remained, even in this country, still more on the Continent, a prevalent feeling in favor of some variety of Classic style as the style for a large mansion, as being capable of taking an expression at once homelike and grandiose. We cannot, certainly, apply such an expression as "homelike" to the class of mansion with a large portico and colonnade like the end of a Roman temple imbedded in the house, which became the fashion for some time after the days of Wren and Inigo Jones. But when this temple end—this exaggerated and practically useless portico—is got rid of, our house architecture on the Renaissance model shows a good deal which is eminently successfal and suitable for its purpose.

This, however, is as to large and isolated houses. When we come to smaller houses, we find two well-marked divisions, street houses, and country cottages and small dwellings. Street architecture, as far as the average people's houses are concerned—anything worth calling street architecture, that is to say—has had a very short and broken life. There has been, probably, a great amount of really picturesque street architecture, in such cities as London, for example, which has perished entirely owing to its frail construction and materials; and in London, of course, partially by the Fire. What really made the sort of street architecture which we now regard as picturesque, such as that of Nuremberg and what is left of Chester, was in great measure the fact of cities being inclosed with walls, and therefore limited in area. Hence the narrow streets, the overhanging upper stories, which look so well in a sketch; they were the result of efforts to utilize every square foot of space inside the walls, in times when to live outside the walls might be really unsafe under certain circumstances. This influence no longer operates in the more civilized parts of the world; and there are influences operating in the opposite direction, operating to produce dull uniformity and regularity, and even to compel these qualities to a certain extent. Conviction of the danger in towns of improper building construction and inflammable materials has led to legislation which it seems to have been, and no doubt always would be, difficult to frame so as to be practically applicable to all cases, without almost compelling a certain uniformity of style and tending to promote the very opposite of a picturesque town architecture. It is difficult, but not impossible, to frame legislation which shall provide for sanitary conditions and security of construction without interfering too much with individual taste in building, or reducing our streets to dulness and uniformity. In the case of smaller houses in the country there has been always a great deal of picturesque character arising almost entirely from the fact that local buildings were made with local materials and in local methods. Each district had a character of its own in its house and cottage architecture, a character which was almost certain to harmonize with the landscape, from the very fact that the materials were local. The railway, the great leveler, is now doing much to modify and interfere with this local character and picturesqueness in country dwellings. Bricks can be easily brought where local stone would have been used by a former generation; slates are available at moderate expense where thatch would formerly have been considered quite an adequate covering. In these and other ways the changed conditions of modern life must influence the houses of the future, be they large or small, mansions or cottages, country or town dwellings.

What new development there is in house architecture at present is more in the direction of sanitary provision than of architectural design. Though so much remains to be done, there can be little doubt but that we are entering upon a very great and salutary change in this respect. The more enlightened section of public opinion has been aroused to the importance of the subject, and there can be no doubt that in future those who are able to build houses for themselves will not be content with their architect giving them the number of rooms they want and the architectural style they desire, but will want to know also that every precaution has been taken to remove or intercept every influence that may be prejudicial to health. The sanitary movement is fairly started, and we can have no doubt of its progress. The problem for future house architecture is to combine sanitary fitness with architectural beauty. It is certainly not superfluous to draw attention to this point, since, for whatever reasons, it is only too obvious that the taste for the sanitary and the picturesque seem to be far too antagonistic. Some members of the profession are vexed and irritated with the requirements of sanitation, and are prone to shuffle off the responsibilties thereof on to other shoulders. On the other hand, nearly everything connected with sanitation seems to be, at present, ugly as a matter of course. The very look of the publications of sanitary publishers "bewrayeth" them. "What a hideous-looking cover," said a visitor the other day, glancing at a pamphlet on our table. "Yes," we replied, "it is a sanitary publication." But the fault is on both sides. The sanitary reformer's work is genuine, but not beautiful. The picturesque architect's work may be beautiful in a certain sense, but unfortunately it is not always genuine, even on its own ground. It is a masquerade. The taste for it is the result of a half-view of the subject. Some architects think that the sort of thing which pleases them and their friends in their own sketch books now, will, if reproduced, equally please in its imitated form. It may for the moment, but it will not be sketched by other architects of future generations, for more reasons than one. Not only will the fashion of taste have changed, but a new way of looking at the subject of house building will have grown up with the increase of sanitary knowledge, and the picturesque house, with its extra gables and its twists and angles made for mere picturesqueness will not recommend itself to more practically-educated generations. For be it remembered that what we now admire as picturesque street architecture in old towns represents also about the most unhealthy form of domestic architecture that could be, in many cases. Materials subject to much decay, close and unventilated corners, a multiplicity of weak points for the invasion of wind and weather; these are among the characteristics of the old picturesque street views which we like to sketch. It may be found that a wider diffusion of knowledge as to the sanitary construction of dwellings will very materially alter the estimation even of the unconscious picturesqueness of the buildings of the pre-sanitary era. That which looks very pretty to those who have no practical acquaintance with the subject looks only puerile to those who have. We remember looking at Martin's picture of "The Plains of Heaven" in company with a yachting man. Our companion was indignant at the gilded barges on which the blessed were floating over the celestial sea. He should have hoped, he said, to find in heaven yachts of better build and sailing power than he had ever met with in terrestrial water. To the landsman the gilded barges might seem very sumptuously and picturesque; the nautical man only saw them as clumsy and "leewardly" craft. In like manner a generation more instructed in sanitary conditions of building may learn to look with a very different eye on what we now call "picturesque" town architecture, and associate it only with ignorance or carelessness of the sanitary conditions of building, of such primary importance in crowded towns.

Have we done, then, with picturesque house building? We hope not; only we must find a more practical and more beautiful species of picturesque. It must be a picturesque, that is, as the French say, *choisi*, chosen, selected, deliberately developed, not growing up spontaneously, not imitative of that

which grew up under different conditions. The picturesque of old towns was, as we have said, to a great extent imposed by the barrier surrounding the walled city of the past. The picturesque of rural houses arose from the employment of the materials and methods of the district with a kind of spontaneous freedom. The employment of the materials of the district in country buildings we have always urged where possible—that is, where they are practically suitable and adequate—as one means of securing harmony with the landscape. But the time is at least not far off when this spontaneous freedom must disappear even from rural houses. Intercommunication breaks down the barriers of provincialism in habits of speech and habits of living, and must do so too in regard to habits of building. It will become a recognized responsibility with landlords that even rural cottages must be well built and in accordance with the best and most healthy conditions in regard to materials and arrangement. In regard to town houses, we have officially recognized and legislated to this end already to a considerable extent, although the working of the legislation has not always been by any means satisfactory, partly owing, perhaps, to its attempting rather too too much in detail; the really desirable provisions of the law are too often evaded or only carried out at the point of much compulsion, while the suggestion which building legislation makes towards building every house according to a uniform pattern is only too well acted upon.

The result of these considerations in regard to average house architecture would seem to be that rural and town building will approach each other more in syle and manner than before. We want in the house architecture of towns (after the due carrying out of sanitary and constructive legislation) the recognition of the fact that it is not necessary that streets built in accordance with certain general practical legislation should therefore be marked by a dull uniformity; we want something of the variety and the special character which the exercise of individual taste should lead to, carried out always in subordination to the requirements of health and security from fire, and of general convenience; not, as in the old picturesque style of town, with an entire ignoring and trampling under foot of all these considerations. The rural dwelling must undergo some change in the opposite direction; some of its specially rustic character, its low unhealthy rooms and its little insufficient windows, must give place to better lighted and ventilated rooms, and the local traditions of building must in some cases give way to the use of better materials and methods. But all these conditions may be observed without reducing a country cottage to the appearance of a slice of a street cut out and put down in the country. It may be a country cottage still; but it must be a country cottage carefully and scientifically built, not one allowed to grow up in its place like a tree.

In regard to houses of the higher class we seem at present to vary between some form or other of the old Classic mansion, and a form of house which endeavors to be strikingly picturesque and homelike; the latter form much predominating among recent houses. The completely Gothic house, with high-pitched gables, has not had a long lease; it seems now to be getting quietly dropped. The ultra-picturesque house of the day we hold to be a sham to a great extent, though a natural reaction against the ultra-formality of an earlier part of the century. Many of these houses, which seem to affect to have been tumbled together in a heap, to be ingeniously accidental, will be laughed at or wondered at, perhaps pulled down and altered, as ugly things, by those will inherit them. Our impression is that a type of house design founded on the Renaissance is more likely to command lasting goodwill than any of these picturesque vagaries. But then it must be a type produced by improving on Renaissance types, not by bringing together a number of corrupt and debased details of the decadence of the Renaissance. The reason we lean to Renaissance, rather than to the picturesque for modern houses of the better class, is that the Renaissance house in its best form represents the domestic architecture of culture much more than does the irregular and studiously picturesque house. The house of a man of culture should appear studied, refined, "*choisi*"

in its architecture; not thrown together, an "*indigesta moles*," however picturesquely. The fault of the Renaissance houses of this country has mostly been that they were too formal and scholastic in arrangement and style. There is no need to follow precedent in that respect. We should wish to see the gentleman's house of the future no reproduction or imitation of houses of the past, no embodiment of cooked up picturesqueness, but a style of house recalling the most refined and thoughtful periods of society, stately without formality; homelike, but the home of dignity, education and refinement: the home of a cultivated man and woman of the world. The present very prevalent taste for "thrown-together" houses, heaped-up roofs, little windows, and so on, seems to us essentially a taste belonging to provincialism rather than to the character of a citizen of the world, as every educated man should be. We hope to see this rather puerile taste, pass away, and to see the house of the future take a more dignified and refined form, combining sanitary completeness, variety and charm in plan and arrangement (a much better kind of picturesque than simply cutting up the exterior skyline), and a certain palatial though not formal dignity—a habitation which would appear rather the result both of scientific and artistic culture.

THE QUALITY OF STEAM.

By JOHN W HILL, M. E.

A Paper read before the American Railway Master Mechanics' Association at the Providence Convention, June, 1881.

Experience shows that steam always carries a certain percentage of water in suspension as it rises from the body of water of which it is formed.

This percentage will vary as between different forms of boiler, and the same boiler operated under different conditions.

The water so suspended in the steam is known as water entrained or as primage.

The raising of the water in a boiler by induction when a large steam pipe is suddenly opened, is entirely independent of the water entrained, and is not meant by any allusion to primage in this paper.

I believe it is a fact observed in chemistry that anhydrous gases cannot be obtained by direct vaporization, and that a special drying process is necessary to saturate or remove the liquid always entrained in the gas upon its first formation.

Saturated steam (that is, steam charged with such an amount of heat that any reduction thereof would produce condensation, and any increase thereof would produce super heat) is substantially a perfect gas and is usually so considered in all formulæ upon its action in a steam engine.

Our best information upon the temperature (heat) of saturated steam at various pressures is from the experiments of Regnault, *Comptes Rendus*, 1847, with which all steam engineers are sufficiently familiar to avoid the description of his apparatus or the circumstances under which his experiments were made, at this time.

It is proper to state, however, that the experiments of Regnault were to ascertain the relations of temperature, pressure and density of steam; and as a corollary to determine the specific heat of steam and water at various boiling points.

The determination of the relation of density and pressure was never made by Regnault, the only recorded experiments upon which were by Messrs Fairbairn & Tate several years later.

It is now well known that the steam engine is a heat engine, that the water which is vaporized to form steam is simply a vehicle in which we store up the heat of the fuel and which parts with a portion of this heat in transit through the engine; partly by conversion of heat into work, partly by conduction and radiation through the walls of the cylinder, and partly by the cooling

effect of the atmosphere on the piston rod.

No steam is expended in operating an engine; for the same weight of water as vapor which enters the cylinder by the steam pipe also leaves the cylinder by the exhaust pipe.

If we deliver one thousand pounds of steam at a given temperature to an engine through the steam ports, we shall draw off through the exhaust ports precisely the same weight of steam at a lower temperature. But during the passage of this steam through the engine a certain reduction of temperature has occurred, and the efficiency of the engine is a function of the limits of temperature between which the steam enters and leaves the cylinder, as enunciated by the junior Carnot more than fifty years ago.

To illustrate the efficiency upon the heat basis let us suppose an engine condensing—consuming—sixteen and one-half pounds of steam per hour, connected with a battery of boilers furnishing ten pounds of steam per pound of coal from the temperature of the feed. Let the thermal value of the coal be taken at 15,000 units, and estimate seventy-five per cent. of this, or 11,250 units, as contained in the steam above the temperature of feed water. Then the efficiency of such an engine would be

$$100 \times \frac{11250 \times 1.65 \times 772}{33000 \times 60} = 13.82$$

per cent., or of every hundred horse power resident in the heat expended in working the engine less than fourteen are utilized. The remaining eighty six horse power going out in the exhaust.

It is well known that the best economy we have any record of has been obtained from pumping engines, and that a duty of one hundred millions foot pounds per hundred pounds of coal is seldom attained. Now our condensing engine working upon sixteen and one-half pounds of steam, or one and sixty-five hundredths pounds of coal per hour, represents a duty of

$$\frac{33000 \times 60 \times 100}{1.65} = 119{,}988{,}000$$

nearly one hundred and twenty millions foot pounds.

From which it appears that *fourteen per cent.* is about a maximum efficiency with our present knowledge of construction.

The object of this paper is, however, not to discuss the economy of steam machinery, but to show the necessity for an exact knowledge of the thermal value of steam, in estimating the economy of engine and boiler performance.

To illustrate the effect of a lack of knowledge of the quality of steam furnished by boilers, let us suppose a temperature of feed of 212 F, an expenditure of coal of one thousand pounds, a consumption of feed water of twelve thousand pounds, and a boiler pressure by gauge of one hundred and twenty-five pounds.

The apparent evaporation from the temperature of feed in this instance is twelve pounds of steam to one of coal.

Without information to the contrary, and in accordance with the usual practice, we would accept this as the evaporation, and pronounce the result as extremely satisfactory.

Suppose, however, the temperature of the steam instead of being at saturation (1221.53 units), contained as a mean per pound only 1135 units; then the actual evaporation instead of being twelve to one, would be ten and eight-tenths to one, and this instance supposes an efficiency of furnace and boiler of nearly seventy-five per cent., and a thermal value of 15,000 units per pound of coal. In brief, supposes a quality of coal and efficiency of furnace rarely obtained.

None of the usual devices applied to steam boilers are capable of measuring the thermal value of steam, and recourse is had to special apparatus for this purpose.

Two distinct forms of calorimeter have been used; one the continuous calorimeter, in which the condensation of a certain small percentage of the steam is maintained during the entire trial of a steam engine or boiler, and the other the intermittent calorimeter, with which at stated intervals known weights of steam are drawn from the boiler or steam pipe, and condensed in known weights of water.

The continuous calorimeter consists usually of a coil of brass pipe or copper pipe of one quarter to half inch diameter of bore, containing thirty to fifty lineal feet. This coil is placed within a tin

can through which the circulating water passes from below upwards.

The upper end of the worm is connected with the steam pipe or steam drum of the boiler, and the lower end terminates in a neck which delivers the condensed steam into a receptacle mounted upon a carefully-balanced scale, with which the condensation is weighed from time to time, and dumped.

The circulating or condensing water is measured by tanks of known capacity, or through a Worthington meter, the error of which is known by test.

Standing thermometers are located as follows: one in the injection pipe, by which the circulating water enters the apparatus; one in the over-flow nozzle, by which the circulating water leaves the apparatus, and one in the neck of the worm from which the water of condensation flows.

Should there be an indication from the calorimeter data of super-heat in the steam, an additional thermometer should be inserted in the head of the worm or in the steam pipe leading to it, to measure the super heat independently and check the record of the calorimeter.

Steam flows through the worm and is condensed, the heat being transferred through the walls of the coil to the circulating water.

The temperature of the circulating water is elevated through a range represented by the difference of temperature of the inflow and outflow.

The temperature of the condensation as it leaves the calorimeter is read from the thermometer in the neck of the worm.

The temperature of the steam is the unknown quantity which we seek.

To illustrate the action of the continuous calorimeter assume a weight of steam condensed of one hundred pounds, a weight of circulating water expended in condensing it of 2,000 pounds, a temperature of inflow of 50 F, a temperature of outflow of 105 F, and a temperature of condensation of 60 F; then temperature of steam neglecting small effect of variation in the specific heat, is:

$$60 + \frac{2000 \times 55}{100} = 1160 \text{ F.}$$

Assume the steam as it entered the calorimeter, at a pressure of 135 pounds by gauge or 150 pounds absolute, at which pressure the temperature of saturation is, according to Regnault, 1223.18 F. Then difference of temperature is 63.18 units, indicating that a portion of the water was entrained in the steam.

To estimate the percentage of primage we must bear in mind that the water in the boiler is first heated to a temperature of 362.56 F (corresponding to a pressure by gauge of 135 pounds), before vaporization takes place; and that an additional temperature of 860.2 units is necessary to vaporize the water so heated; and that the discrepancy in the thermal value of the steam applies to the temperature of vaporization, whence the water entrained as primage becomes

$$100 \times \frac{63.18}{860.2} = 7.35 \text{ per cent.}$$

The intermittent calorimeter consists of a water-tight vessel (preferably of wood to avoid transfer of heat to or from the contents thereof by conduction and radiation) mounted upon a sensitive scale, into which a known weight of water is drawn.

A small steam pipe, usually three quarters inch diameter, closely connected with the main steam pipe or steam drum of the boiler, dips into the vessel on the scale, and is provided with a cock or open-way valve to regulate the delivery of steam into the weighed quantity of water.

The temperatures are taken with a hand thermometer.

As suggested, a known weight of water is first weighed into the tank on the scale, usually some convenient quantity to estimate from, as one hundred or two hundred pounds, of which the probable condensation in the small steam pipe usually forms a part.

The amount of condensation which will collect in the steam pipe between observations will vary with the quality of steam, and must be blown out to clear the pipe before the weighed quantity of steam to be condensed is blown in.

The weight of water and condensation blown out of the pipe having been justified, the temperature of the contents of the tank is carefully taken with a reliable thermometer, and five or ten pounds of steam blown in and condensed. (The weight of steam condensed should be as

large as consistent with a limited temperature of the contents of the tank on the scale, to obtain a high range of temperature; since errors of weight are less liable to occur than errors of temperature, and the greater the range of the mercury the smaller the effect of errors of observation.)

The desired weight of steam having been condensed the flow through the pipe is promptly suppressed and a second temperature of the contents of the tank is taken.

The first temperature from the second temperature represents the range of the contents of the tank.

To illustrate the principle of the intermittent calorimeter let the following data be assumed:

Weight of condensing water,	100 pounds.
" " steam condensed.	5 "
Initial temperature condensing water..............	60 F.
Final temperature condensing water..............	115 F.
Range..................	55 F.

and the temperature of steam is

$$115+\frac{100\times55}{5}=1228 \text{ F.}$$

Supposing steam as before at a pressure absolute of 150 pounds, the difference between the quality in the illustration and saturated steam is 4.82 units corresponding to a super heat of

$$\frac{4.82}{.475}=10.15 \text{ F.}$$

I have not detailed the construction and action of the two well-known forms of calorimeter with the expectation of adding any to your knowledge thereof, but to bring the processes fairly before you previous to calling your attention to some of the results of my experience with the instruments.

I shall not attempt, in the short time which, by courtesy, you allot me, to detail all my experiments with the calorimeter, as these are many and would frequently be simple repetition of results, but shall refer only to a few experiments to show the value of investigations of this class.

The first results we will examine are from a series of four experiments upon boilers set with smoke-preventing furnaces for the Cincinnati Industrial Exposition for 1879.

The first case was a return tubular containing 963.64 superficial feet of heating surface, and worked at a capacity equivalent to 2.77 pounds of steam per foot of heating surface per hour, which gave a temperature of steam of 960.46 units indicating, with a pressure by gauge of 38.75 pounds, a primage of 26.26 per cent.

The apparent evaporation from the temperature of feed (70.02 F.) per pound of coal was 7.59, but the actual evaporation from same temperature was only 5.6 to one.

The second case was a return flue boiler containing 519.45 superficial feet of heating surface, and worked at a capacity equivalent to 1.73 pounds of steam per foot of heating surface per hour, which gave a temperature of steam of 964 73 units, indicating with a pressure by gauge of 80.29 pounds, a primage of 29 13 per cent.

The apparent evaporation per pound of coal from the temperature of feed (166.01 F.) was 5.84, but the actual evaporation from same temperature was 4.14 to one.

The third case was a battery of two return tubular boilers containing 880.16 superficial feet of heating surface, and worked at a capacity equivalent to 3.20 pounds of steam per foot of heating surface per hour, which gave a temperature of steam of 1005.93 units, indicating with a pressure by gauge of 76.18 pounds, a primage of 23.19 per cent.

The apparent evaporation per pound of coal from the temperature of feed (169.11 F.) was 9.69, but the actual evaporation was 7.45 to one.

The fourth case was a direct tubular boiler containing 327.79 superficial feet of heating surface, and worked at a capacity equivalent to 2.96 pounds of steam per foot of heating surface per hour, which gave a temperature of steam of 1441.35 units, indicating with a pressure by gauge of 81.60 pounds, a super heat of 18.83 per cent.

The apparent evaporation per pound of coal from the temperature of feed (74.55 F.) was 8.80, but the actual evaporation upon the basis of saturated steam was 10.66 to one.

This boiler was set and worked simply

for test purposes, and was furnished with super-heating surface.

The continuous calorimeter was used in these experiments.

The next results to which I shall refer are the calorimeter tests for quality of steam during the trials of steam engines at the Millers' Exhibition, Cincinnati, 1880.

In this instance the experiments were all made with the same boilers operated under approximately the same conditions from day to day.

The boilers, two return tubular, contained 1327.24 superficial feet of heating surface, and were worked at the following capacities in pounds of steam per foot of heating surface per hour, for six different trials—2.53, 2.42, 2.32, 2.41, 2.42 and 2.63—with corresponding temperatures of steam of 1243.84 units, 1211.3 units, 1315.86 units, 1255.74 units, 1301.65 units and 1313.11 units.

Of these temperatures only one, the second, indicates primage, all others exhibit a slight super heat.

The primage at 92 54 pounds pressure by gauge in the second experiment was .46 per cent.

The percentage of super heat at 92.50 pounds pressure by gauge in the first experiment was 2.3; in the third experiment, with steam pressure at 91.65 pounds by gauge, 8.3 per cent.; in the fourth experiment, with steam pressure at 91.48 pounds by gauge, 3.34 per cent.; in the fifth experiment, with steam pressure at 91.44 pounds by gauge, 7.09 per cent., and in the sixth experiment, with steam pressure at 91.54 pounds by gauge, 8.06 per cent.

The continuous calorimeter was used in these trials.

The former results were from four different boilers of different forms and dimensions, and operated at different steam pressures and rates of evaporation, with a range in the quality of steam from 19 per cent. of super heat to 29 per cent. of primage, whilst the last six results were all from the same boilers, operated at different times, under approximately the same steam pressure and rates of evaporation with a range in the quality of steam from 8.3 per cent. of super heat to one-half per cent. of primage.

From which it appears that with the same boiler or boilers, operating under similar conditions, an approximately uniform quality of steam should be had, and that the quality of steam in any one instance cannot be assumed for another, unless the conditions are precisely alike.

The next results to which I shall refer are from three different trials upon the same boilers operated with similar steam pressures, and at different rates of evaporation.

The boilers, two in the battery, were of the return tubular variety, containing 932.02 superficial feet of heating surface.

During the first trial, steam was made at the rate of 4.09 pounds per foot of heating surface per hour, with a resultant temperature of 1153.09 units, indicating a primage at 92.59 pounds by gauge of 7.08 per cent.

During the second trial the boilers were worked at an evaporation equivalent to 2.86 pounds of steam per foot of heating surface per hour, with a temperature of steam of 1199.04 units, indicating, with a pressure of 92.95 pounds by gauge, a primage of 1.92 per cent.

During the third trial the boilers were worked at a rate of evaporation equivalent to 2.90 pounds of steam per foot of heating surface per hour, with a temperature of steam of 1174.17 units, indicating, at a gauge pressure of 92.28 pounds, a primage of 4.75 per cent.

These experiments were made with an intermittent calorimeter.

In all experiments exhibiting a small primage in the steam, as a super heat, the boilers were set to expose more or less of the steam room to contact with the hot gas.

The next results are from a series of three experiments with a small locomotive boiler, operated standing.

For the first trial the heating surface was 288.75 superficial feet, and ratio of heating to grate surface 25.9 to one.

The boiler was worked at a capacity equivalent to 8.49 pounds of steam per foot of heating surface per hour, with a temperature of steam of 1150.98 units, indicating at 105.5 pounds pressure, by gauge, a primage of 5 per cent.

The apparent evaporation per pound of coal was 4.45, and the actual evaporation was 4.09 to one.

For the second and third trials the heating surface by the introduction of a water bridge into the fire box was in-

creased to 300.7 superficial feet, with a ratio of heating to grate surface of 41.67 to one.

During the second trial the boiler was worked at a rate of evaporation equivalent to 9.39 pounds of steam per foot of heating surface per hour, with a temperature of steam of 1181.76 units, indicating at 98.25 pounds pressure, by gauge, a primage of 4.33 per cent.

The apparent evaporation in this case was 7.58 pounds, and the actual evaporation 7.25 pounds of steam to one of coal.

During the third trial the boiler was worked at a rate of evaporation equivalent to 9.77 pounds of steam per foot of heating surface per hour, with a temperature of steam of 1259.29 units, indicating a super heat of 88.67 degrees F., at a pressure by gauge of 100.7 pounds.

The apparent evaporation was 6.41 pounds of steam per pound of coal, and the actual evaporation upon the basis of saturated steam was 6.65 to one.

The rate of combustion and evaporation was higher for the third trial than for the second, with a better quality of steam and a reduced economy.

In these trials the coal was burned within five or six per cent. of the total weights charged, and the calorimeter results can be fairly compared without correction.

The next result to which I will refer is from the boiler of a "Rogers" engine on the Ohio and Mississippi railroad, in a running trial from Vincennes to Seymour, made last July.

The heating surface was 984.33 superficial feet, and the rate of evaporation equivalent to 9.51 pounds of steam per foot of heating surface per hour, with a temperature of steam of 1192.11 units, indicating a primage of 3.4 per cent. at a pressure by gauge of 125.56 pounds.

The apparent evaporation in this instance was 3.97 pounds per pound of coal, and the actual evaporation was 3.83 to one.

The poor economy of this boiler was largely due to the high rate of coal consumption (146.25 pounds per superficial foot of grate per hour).

With large grate areas and a reduced rate of combustion per superficial foot of grate per hour, the economy of locomotive boilers may be materially improved, as shown by the results obtained with the "Wooten" boiler on the Philadelphia and Reading railroad.

I am aware that some of my professional friends are not seized of my faith in the reliability of calorimeter results; but I am unable to obtain from them any better objection than that some modifying data has been overlooked or neglected in those cases which do not meet their approbation. However, when they agree, as they invariably do, that condensed steam and condensing water may be accurately weighed, and that approximately accurate temperatures may be had with good makes of thermometers; then I can conceive no other objections to accepting the results of calorimeter experiments than the personal errors of observation which pervade all mechanical investigations.

If the power of steam engines is to be measured by the indicator, or the less reliable dynamometer or friction brake; if the economy of boilers and engines is dependent upon the accuracy of weighing scales; if steam pressures are to be taken from spring gauges and temperatures read from mercurial thermometers, and such results are held to be reliable for absolute and comparative effect; then the same reliability must, in simple justice, be accredited the calorimeter; for it depends solely upon correct weights and temperatures, and involves no complex or uncertain quantities in the operation.

A correspondent describes the following as a filler for porous hard woods: "Take boiled oil and corn starch, and stir into a very thick paste. Add a little japan and reduce with turpentine. Add no color for light ash. For dark ash and chestnut, use a little raw sienna; for walnut, burnt umber and a slight amount of Venetian red; for bay wood, burnt sienna. In no case use more color than is required to overcome the white appearance of the starch unless you wish to stain the wood. This filler is worked with brush and rags in the usual manner. Let it dry forty-eight hours, or until it is in condition to rub down with No. 0 sand paper, without much gumming up, and if an extra fine finish is desired fill again with the same materials, using less oil, but more of japan and turpentine.

RECENT PROGRESS IN THE MANUFACTURE AND APPLICATIONS OF STEEL.

By PROF. A. K. HUNTINGTON.

From the "Journal of the Society of Arts."

At first sight, the title which I have given the paper I am about to bring before you this evening, might lead some to suppose that it was intended to deal with very recent events, such as might have occurred within the last few months, or say a year. Such anticipations would be fully justified were I to address you on recent progress in the applications of electricity, for this offspring of intellects of our own era makes marvelous progress from day to day, until one feels tempted to concede to it a position in the universe similar to that occupied in the human body by nerve force. In fact, the want of continuity between our nerve system and what we may call that of the world is fast becoming less and less. We can already flash our ideas and our voices to the farthest parts of the earth, and the reproduction of the images of material objects by similar means seems to be in a fair way of accomplishment. But the subject of our attention to-night had its commencement in times so remote as to be far beyond the reach of human record, and its rate of progress may be measured by that of the world itself in the Arts and Sciences.

Improvements in the Arts and Sciences have gradually modified the methods of producing iron and steel; and, in their turn, the Arts and Sciences have felt the re-action; for all improvements in the manufacture of iron and steel have been not so much in the production of a better quality of article, but in the cheapening of production, by the application of the principles indicated by the progress of science, and by the use of superior machinery. The direct result of this cheapening has been to extend the applications of the products in the Arts. To appreciate this, let us glance back, and see by what means steel was produced up to the year 1855, and what were its applications, and then trace out the causes of the changes which have since taken place in these respects.

The discovery of steel appears to have naturally followed that of the means of reducing iron from its ore. In all primitive methods of iron smelting, steel, in more or less quantity, is inevitably produced. Such methods have been carried on in India and Africa from time immemorial to the present day. A similar furnace has, for several centuries, been employed in Catalonia, in Spain. The comparative cheapness of iron manufactured in other countries by improved methods, is, however, rapidly causing this furnace to pass out of use.

I propose now briefly to describe to you the process in the Catalan furnace, as it is called, in the form into which it last developed in Spain and the South of France, in order that we may clearly understand the essential differences between iron and steel, both as regards their composition and properties, and also the conditions requisite in the production of each.

Mode of Conducting the Process.—The ore is crushed by the hammer, and divided by sifting into lumps ("mine") and very coarse powder ("greillade"). The furnace being still red hot from the last operation, it is filled with charcoal nearly to the twyer, the hearth is then divided at a point about two-thirds distance from the twyer into two parts by a broad shovel; on the blast side a further quantity of charcoal is added, whilst that on the other side having been rammed down firm, ore is added, so as to fill that part of the furnace; on this is placed moistened charcoal dust, except at the top. A good blast is then turned on, and if the whole is in good order, jets of blue flame at once issue from the uncovered portion of the ore. After a few minutes the pressure of the blast is lowered to 1.5 in. of mercury. At intervals during the pro-

cess—which lasts about six hours—the blast is gradually raised until it reaches about 3 in., the maximum usually employed.

During the whole of the process, at short intervals, "greillade" and charcoal are added, and well moistened with water, to prevent too rapid combustion. After about two hours from the commencement, the wall of "mine," *i. e.*, ore in lumps, is pushed well forward under the twyer, and more "mine" is thrown into the space thus made; this part of the process is also subsequently repeated at intervals, until sufficient has been added to form a lump of iron or *masse* of the required size. From time to time slag is removed by opening the tap hole. At the completion of the process, a mass of metal is obtained weighing about 3 cwt., which invariably consists partly of soft iron, and partly of steely iron and steel.

Reactions in the Furnace.—We have seen that in the one part of the furnace only charcoal and "greillade" are introduced, and in the other only lumps of ore. That the ore should be in lumps at that part is a very important point, for in this way the hot reducing gas, carbonic oxide (CO), generated by the action of the blast on the charcoal, is able to pass freely through the mass of the ore, the effect of which is that the water of hydration and the moisture are first driven out by the heat, and then the ore having become easily permeable, the carbonic oxide reduces it to metallic iron, thus, $Fe_2O_3 + 3CO = Fe_2 + 3CO_2$. There are, however, several stages in this reduction, magnetic oxide being first formed thus, $3Fe_2O_3 + CO = 2Fe_3O_4 + CO_2$; and protoxide is next formed before metallic iron is obtained thus, $2Fe_3O_4 + 2CO = 6FeO + 2CO_2$, and $6FeO + 6CO = 3Fe_2 + 6CO_2$. At the same time that these reactions are going on, the ore has become impregnated with carbon, derived from the decomposition of the gases with which it is charged. That this would be the case, the experiments of Mr. Lowthian Bell and others can leave no manner of doubt.

On the twyer side, where are placed the charcoal and "greillade," the latter, as the charcoal is burnt away, descends rapidly, and, to a considerable extent, doubtless, escapes reduction, for the arrangement of the blast is such that most of the reducing gas is projected on to the lumps of ore and does not pass up through that portion of the furnace occupied by the charcoal and "greillade," which, besides, are constantly damped. This "greillade" is much richer in silica than the larger pieces, from which it results that the quantity of slag will vary with the "greillade" added. It is always very rich in oxide of iron.

Now, what happens in this process appears to be this: carburized iron is produced by the gradual reduction and fusion of the lumps of ore, and this, coming in contact at the bottom of the furnace with slag, very rich in oxide of iron, the carbon of the one combines with the oxygen of the other, and the result is that iron containing more or less carbon is produced, according as much or little oxide was present.

The obvious conclusion would be, that the less there was of "greillade" present the more steely would be the iron; in practice this is found to be the case. This circumstance would naturally suggest the total suppression of the "greillade," when it was desired to produce steel. This would, however, be impracticable, for it is necessary that some of the oxide of iron should remain unreduced in order to flux off the silica, which occurs in considerable quantity in the ore. In the blast furnace, this difficulty is got over by employing lime; but lime at the temperature of the Catalan furnace would not produce a sufficiently liquid slag.

All that can be done, then, is to employ every available means to prevent decarburization. Accordingly we find that when steel is required, in addition to using less "greillade," the slag is tapped out more frequently, so that the lump of iron, as it forms, may remain as little time as possible in contact with it. The bank of ore is exposed for a longer time to the reducing and carburizing gases, and is pushed more gently towards the twyer, so as not to become decarburized by the air which has not had time to combine with the carbon of the charcoal. Lastly, manganese should be present. It is found that the presence of manganese has a very important influence, which is probably due to its power to replace iron in the slag. A slag

containing manganese is more liquid than if it contained iron alone, and, according to François, has not the same tendency to cause decarburization at the temperature of this process.

In order, then, that steel may be produced by this process, every precaution is taken to cause as much carburization as possible; the unavoidable presence of oxide of iron in the slag, and the low temperature, effectually preventing the formation of cast iron; the former, indeed, making it very difficult, as we have seen, to obtain steel.

It might be said, why not increase the temperature, so as to obtain a liquid slag without using oxide of iron? If the temperature were increased, cast iron, instead of steel, would be produced; in fact, that is exactly how cast iron first came to be obtained in blast furnaces.

I have gone rather fully into this process, because the principle of it is not always well understood. Rightly looked at, it explains how steel was first obtained, and what the essential conditions are, in the production of steel. When, owing to the increased size of blast furnaces, and the consequent increase in temperature, cast iron became the only product, it naturally followed that this substance should be treated with a view to the production of steel. This was first effected in the fining hearth, and formed an important industry in Styria, Carinthia, the Tyrol, and other places, in some of which it is still carried on.

The operation was conducted in a finery, similar in construction to those employed in the production of iron—in fact, iron and steel are often produced alternately in the same finery. This furnace, in its simplest form, consists essentially of a shallow quadrangular hearth, formed of cast iron plates. In one side is a twyer, inclined at an angle of 10° to 15°. The bottom is kept covered with a layer of charcoal.

In the Siegan district, a piece of pig iron, weighing 50 lbs. to 60 lbs., is placed on the hearth, having been previously heated; the hearth is then three-parts filled with burning charcoal; on it is placed a portion of the cake produced in the last operation, and which has been kept hot in burning charcoal, at the back of the furnace. The remainder of the hearth is then filled up with charcoal. The other six or seven pieces into which the last cake was divided, are placed on the top. In this process the production of steel, and the reheating of that obtained in the last operation, preparatory to working it under the hammer, are conducted together. The blast is turned on. The piece of pig iron forms into a pasty mass; cinder, rich in oxide of iron, produced during the latter part of the preceding operation, is then thrown in; a second piece of pig iron, weighing about 100 lbs., is added, and, afterwards, four or five pieces of spiegeleisen, weighing each about 100 lbs., are successively added. (Spiegeleisen is cast iron, containing manganese, in this case about 4 per cent.) If the metal is found to be too much decarburized, more spiegel is added. The cinder is usually allowed to rise 2 inches or 3 inches above the cake of metal, any excess being tapped off. There are several modifications of this process, but I have said enough to make the principle clear. In this process, as in the Catalan, it is impossible to obtain a homogeneous product. The principle in both is essentially the same, viz., decarburization by oxide of iron. In the finery process, in addition to the oxide added in the form of cinder and scale produced during the working of the metal under the hammer, some results from the reheating, which we have seen is carried on at the same time. In this process manganese also plays an important part, and we shall see that in every process for the production of steel, manganese is used with great advantage.

With one notable exception—the cementation process—the early methods for the production of steel were simply modifications of the methods for producing malleable iron. Accordingly, we find that the introduction of the puddling process, by which malleable iron is produced in a reverberatory furnace, was soon followed by a similar process for the manufacture of steel.

The essential difference between the finery and the puddling process consists in the use of a reverberatory furnace, the manipulation of the metal and the regulation of the temperature being thereby greatly facilitated. The decarburization is effected by the addition of oxide of iron produced during rolling, and partially by the air which enters the fur-

nace as the metal melts slowly down; manganese is added during the process. It is important that the temperature should be kept low. It is difficult to weld this steel perfectly; this is probably due to the temperature at which the steel has to be worked, being too low to make the cinder sufficiently liquid to enable it to be squeezed out under the hammer to the same extent that it is in the case of malleable iron. This difficulty has, however, been got over by completely fusing the steel before working it, so as to enable the slag to completely separate. In this form metal manufactured by this process has been largely used by Krupp. This defect is common to all steel which has been produced without fusion.

The same principle as that which regulates the production of steel by the foregoing methods is taken advantage of in the Uchatius process, which was patented in 1855.

Pig iron is first granulated by running it while molten into cold water. The granulated metal is then mixed with about 20 per cent. of roasted spathic ore, crushed fine; the mixture, to which a little flux has been added, if necessary, is then fused in clay crucibles. If very soft steel is required, some wrought-iron scrap is added.

Lastly, in this category we have a process which consists in heating cast iron, but not so as to soften it, in oxide of iron, in the form of ore or iron scale. In this way partial, or even total, decarburization of the metal can be produced at will.

So far we have seen, then, that the difference between iron and steel is merely one of degree depending on the amount of carburization. The methods we have considered, in fact, are only modifications of those practiced for the production of malleable iron.

We will now pass to the brief consideration of the different methods of procedure for the production of steel, which, however, I think I shall be able to show naturally resulted from the observation of phenomena occurring in the first process we have had under consideration.

These processes have for their object to impart a certain amount of carbon to malleable iron. The Hindoos have practiced one of them from time immemorial. They place in unbaked clay crucibles of the capacity of a pint, a piece of malleable iron, and some chopped wood, and a few leaves of certain plants; the top of the crucible is then closed with clay, and the whole well dried near a fire. A number of these crucibles are then strongly heated for about four hours in a cavity in the ground, by means of charcoal and a blast of air forced in by bellows. There is some reason to believe that an excess of carbon, over that required to produce the hardest steel, has to be added, in order to fuse the metal at the temperature which can be commanded in these furnaces. Before being drawn out into bars, the cakes of metal obtained in this way are exposed in a charcoal fire during several hours, to a temperature a little below the melting point, the blast of air playing upon them during the time. The object of this is, doubtless, to remove the excess of carbon.

In 1800 a patent was taken out by David Mushet, for a process in every respect analogous to that just referred to. He appears, however, to have applied it to the manufacture of a metal low in carbon, and therefore intermediate between iron and steel, partaking, in a certain degree, of the properties of both, corresponding, in fact, to what we have referred to as steely iron. Since this metal must have been in a state of fusion, Mushet must have brought to bear upon it a very high temperature. The manufacture was conducted in crucibles.

In another method referred to by Biringuccio, in 1540, steel is produced by keeping malleable iron in molten cast iron until it became pasty, and on examination was found to possess the properties of steel. In connection with the theory of steel manufacture this process is of great interest. It shows that iron in a strongly-heated condition is capable of absorbing carbon by direct contact, unless we suppose that carburization is effected by dissolved gases, which is possible, for Graham and others have proved that iron can occlude gases even when it is in a solid state.

If we admit that the mutual affinity of carbon and iron, is such as to cause them to unite at the temperature of molten cast iron, it is then not difficult to conceive how the whole mass becomes

carburized without the intervention of occluded gas. In asking you to concede that the surface of the iron enters into combination with the carbon in this way, I am strictly within fact, as shown by the Hindoo and Mushet processes. A marked case of this kind occurs when sulphur and silver or copper are brought together at the ordinary temperature, combination takes place.

The particles of iron at the surface having taken up carbon, their affinity would be satisfied, but the affinity of the atoms contiguous and beneath would at once come into play, and would only be satisfied by an equal division of the carbon between themselves and those on the surface.

Imagine a man carrying four cannon balls, his strength just sufficing for the task; he encounters an enemy equally strong, but who is unencumbered, and, therefore, in the possession of his whole strength.

For the sake of simplicity, we will call the man carrying the cannon balls A, and the other B. B first applies his whole strength to wrest one ball from A, and succeeds, for the chances are 4 to 1 in his favor, A holding the ball only with a fourth part of his strength, whereas B applies the whole of his. B then tries to obtain another ball from A, and again succeeds, for the force he applies in relation to the resistance offered by A, is as 3 to 2. A and B are now on an equal footing; each is capable of taking up two more cannnon balls, should the opportunity present itself.

Now, let the cannon balls be represented by the carbon atoms, and A and B by the surface and the inner contiguous particles of iron, then the bath of molten cast iron will form a reservoir from which A can re-charge itself. In the meantime other particles, C, will have deprived B of part of its carbon, just as B did A, and B will, therefore, be again in position to obtain carbon from A.

The same reasoning would apply to each successive layer of metal throughout the mass, that on the surface taking up carbon continuously from the bath of molten metal, until, if the process were continued long enough, the malleable iron would become converted into cast iron of the same composition as that in the bath into which finally it would dissolve.

We now come to what is called the cementation process. It is not known when this process was first used. It was well described by Reaumur in 1722. In this method bars of iron are kept at a glowing red heat, surrounded with charcoal in boxes, into which the air is prevented from entering. The operation lasts from seven to ten days, according to the quality of steel required. These bars are never uniformly carburized, and, besides, they contain cinder, as the metal has never been fused. The process had been a long time in use, however, before it occurred to any one to fuse the steel and make it homogeneous. This was done by Huntsman, about 1760. It was the first time that steel had ever been intentionally obtained in a molten state, unless we except the Hindoo process, but the fused product in that case was probably too highly carburized to constitute steel. I have already premised that the addition of carbon to malleable iron, in order to produce steel, resulted from the observation of what took place in the processes first described. It was, in fact, a matter of common observation that iron, no matter whether solid or molten, kept in contact with carbon, became more or less steely. What more natural then than to endeavor to produce steel directly in this way?

By all the processes we have so far reviewed, good steel could be produced, but only in small quantity and at great expence. The applications of steel were, in consequence, very limited; in fact, practically, its use was confined to implements with a cutting edge.

In 1845, Heath patented a process which, had it been successful, would have given him the power of producing steel in quantity. He proposed to melt scrap iron in a bath of molten pig iron in a reverberatory furnace heated by jets of gas. There were two conditions wanting in this method, which caused it to be a failure, viz., a sufficiently high temperature and the power to easily regulate the character of the gases employed. Nevertheless, in this suggestion is to be found the germ of one of the two most important processes of the present day. By the foregoing remarks I do not in-

tend to imply that the idea of mixing wrought and cast iron together to produce steel was originated by Heath. On the contrary, as we should expect, this idea was a very old one. In 1722, Reaumur tells us that he succeeded in making good steel in a common forge in this way. As far as I am aware, however, Heath was the first to suggest the use of a reverberatory furnace and gas for the purpose, and that is the important point.

It may here be pointed out, that the manufacture of steel by this method does not depend by any means entirely on the adjustment of the relative proportions of wrought iron and pig iron, as appears sometimes to be thought by those not specially acquainted with the process. There is a good deal of oxidation going on during the operation, which results in the elimination of an equivalent proportion of carbon from the pig iron.

The dominant idea in treating cast iron for steel had always been to refine the metal by the action of atmospheric air, and this was effected by causing a current of air to impinge upon the surface of the metal, by means either of blowing apparatus or the drawing action of a chimney stack. What more natural than that it should occur to some one to refine iron by blowing air into it, instead of merely on its surface? We find that this idea did actually occur to several persons, widely separated, in the year 1855. It is a noteworthy fact that a very large number of what we call discoveries or inventions are made simultaneously, and independently, in different parts of the world by people who previously had probably never heard of one another.

It would seem as if the records of observations accumulated in men's minds, and in books, until they naturally pointed to certain conclusions. The man who follows up these conclusions, and applies them in practice, is not always the one who first perceived them. To carry out what appears to the world at large as new ideas, requires great strength of purpose, and such a combination of circumstances as to afford an opportunity.

In this year (1855) a patent was taken out by John Gilbert Martien, for refining iron, by forcing air through it as it flowed from the blast furnace or cupola, along runners, to the puddling furnace. This conception was a very important one in the sense that had not others been working in exactly the same direction the same time, it would probably have assisted in working out the problem involved. The process, as detailed in the patent, was impracticable, and shows internal evidence of not having been worked out on a manufacturing scale.

Just after this patent was taken out, we find George Parry, of the Ebbw Vale Works, making the experiment of forcing air through molten cast iron, on the bed of a reverberatory furnace, by means of perforated pipes imbedded in the fireclay bottom. Vigorous action is stated to have taken place, but, unfortunately for the experimenters, the metal, through an accident, escaped from the furnace, and the further trial of the process was discouraged by the managing director. There can be no manner of doubt that had this experiment been continued very important results would have ensued. As the Ebbw Vale Company had bought Martien's patent rights, it would appear that their experiments were really based on his idea. Of this I am not, however, certain, as I am not aware of the date at which they made the purchase.

Two or three months after these experiments, Hery Bessemer took out his now celebrated patent for the production of cast steel, by blowing air through molten cast iron; it should be clearly borne in mind that he had been, for considerable time, previously engaged in experiments on the subject.

Whether Bessemer originally started with the idea of refining pig ready for puddling, and, in the course of his experiments, made the discovery that by the action of the oxygen of the air on the carbon of the pig iron, such an enormous heat was produced that the resultant iron was obtained in a molten state —a thing never before accomplished—I do not know. The only alternative is that he arrived at the same conclusion, by inductive reasoning, which, all things considered, is very improbable.

Bessemer first carried out his process in crucibles, placed in furnaces and arranged so that the contents could be tapped from the bottom into moulds.

Steam or air, either separately or together, and by preference raised to a high temperature, was forced down into the crucible through a pipe. The patent goes on to state that steam cools the metal, but air causes a rapid increase in its temperature, and it passes from a red to an intense white heat.

It was, and still is, to a less extent, an infatuation of patentees, to employ steam in the place of air. Bessemer soon discovered the essential difference which exists in practice though not realized by the excited imaginations of the majority of would-be inventors. Bessemer at first used extraneous heat to start the process, if not, indeed, during its progress, which shows that he was not then aware that the heat created by merely blowing in air would be sufficient.

In his next patent taken out shortly after, however, he dispenses with the furnace round the crucible, and instead of tapping the crucible from the bottom, he mounted it on trunnions, and by tipping it up by machinery, poured the contents from the mouth. This apparatus, devised by Bessemer, is essentially the same as that used at the present day. The way in which he worked out the process in every detail to a grand practical success, in such a short space of time, shows him to have been possessed of a mind of great powers of conception. Having the facts before him, he drew the right conclusions from them with unerring judgment, and from one experiment passed to another suggested by it, until with indomitable perseverance he succeeded in bringing about greater progress in the manufacture of steel in a few months than had occurred in centuries before.

It was very soon found that to produce steel by this process which would work properly, manganese, if not originally present, would have to be added. In the absence of manganese, sulphur and oxygen, in anything more than very minute quantities, makes the steel crumble when worked at a red heat; it is said to be "red short." In the case of the oxygen, the manganese combines with it, and passes it into the slag; but, with sulphur, the reaction is different; its injurious effect is simply counteracted by the manganese; it is not removed from the steel.

At first manganese was only employed in the form of spiegeleisen—a variety of cast iron, containing manganese. The use of this substance was first suggested by Robert Mushet. When, however, it was attempted to produce very soft steels, a practical difficulty arose. If sufficient spiegel was added to impart the requisite quantity of manganese, then too much carbon would have been introduced. This ended in attempts being made to produce spiegel richer in manganese. By suitably adjusting the conditions in the blast furnace, this was soon easily accomplished; and instead of spiegel containing less than 10 per cent. manganese, a 20 per cent. spiegel was produced.

At the suggestion of Bessemer, attempts were made to obtain a still richer alloy. This was accomplished by reducing rich ores of manganese with cast iron in crucibles or in a reverberatory furnace. These richer alloys are known by the name of ferro-manganese. They are employed with great advantage when very mild steel is being manufactured.

By adding at the end of the process a known quantity of spiegel or ferro-manganese, containing a known quantity of carbon, steel of any required hardness could be obtained. There was but one important drawback to the Bessemer process, and that was that phosphorus was not in the least degree eliminated by it; consequently, only the best ores could be employed, which considerably increased the cost of production over that which it would otherwise have been. I will refer to that point again presently,

The year which saw the birth of the Bessemer process was doubly remarkable, for it was at that time that the regenerative system of heating was first introduced by Dr. Siemens. Nothing can be simpler than the principle involved in this method, yet it was destined to play a most important part in the progress of the arts. The idea was to store up the heat escaping in the waste gases from furnaces, and to employ it to raise the temperature of the gas and air previous to their combustion in the furnace. This was accomplished by causing the spent gases to pass through two chambers filled with loose brickwork. When these chambers have become heated to a high temperature, the

waste gases are made to pass through two other similar chambers, and the air and gas necessary for combustion in the furnace are caused to pass through the highly heated regenerators. By causing the ingoing gases to pass alternately, at suitable intervals of time, through each pair of regenerators, a very high and, at the same time, uniform temperature can be obtained in the furnace, without any greater consumption of fuel than in the older methods. The success of this process depended entirely on the fuel being first converted into a combustible gas. This was done in a chamber to which only sufficient air is admitted to convert the carbon into carbonic oxide, which is then conducted by tubes to one of the regenerators to be heated, and thence to the furnace, where, coming in contact with air which has been passed through the other regenerator, it burns, giving out intense heat. It is at once apparent that we have here the very conditions which were wanting to make successful the process patented by Heath in 1845, for not only we have the high temperature which could not then be obtained, but it has become easy to create at will, by regulating the relative proportions of combustible gas and air, either an oxidizing, a reducing, or a neutral flame.

There are two methods now in use for the production of steel in the reverberatory furnace or open hearth as it is called. In France, pig iron and scrap steel are fused together; in England, pig iron is decarburized by means of iron ore, some scrap, however, being generally added for the sake of utilizing it. As in the Bessemer process, the necessary amount of carbon is imparted to the metal by the means of spiegeleisen or ferro-manganese. This process has been largely employed for the production of ship and boiler plates. It has the great advantage that the metal can be kept fluid on the hearth, and its composition adjusted until it is exactly that required.

In 1876, a patent was taken out by M. Pernot, in which it was proposed to produce steel on an open-hearth furnace with a revolving bed, inclined at an angle of 5° or 6° to the vertical. Pig iron previously heated to redness is placed in the bed of the furnace and covered with scrap steel. The bed of the furnace is then made to revolve slowly, the pig gradually melts, and the scrap is alternately exposed to the strong heat of the flame, and then dipped under the molten pig iron. In this way the fusion is very rapid comparatively, the whole mass becoming fluid in about two hours. The process is then completed in the ordinary way. When repairs are necessary, the bed on its carriage is drawn out.

In practice, it is found that these furnaces require very frequent repairing. With the view to make this easier, M. Pernot has arranged a movable roof, which has besides the additional advantage of reducing somewhat the strain on the structure, occasioned by such great variations in temperature. M. Pernot informs me that he has just taken out a patent for an arrangement of his furnace by means of which he can employ gas under pressure, and that within the last few months he has obtained by this means results which have never been equaled before. He states that, in a seven-ton furnace, he has obtained five charges in twenty-four hours. This, at any rate, contrasts favorably with the figures given by Hackney, in 1875. He says five charges, of about four and a half tons each, are got out in each twenty-four hours; the coal used being about eight to eight and a-half cwts. per ton of steel. The averages obtained with furnaces of similar design, and working under similar conditions, but with fixed beds, he states to have been just about half, and the coal used per ton of steel to have been eighteen cwts. Mr. Holley, of New York, has recently stated that they are getting with the ordinary Pernot furnace a seventeen-ton charge in six and a-half hours, all cold stock, except five tons pre-heated scrap.

The Steel Company of Scotland tried the Pernot system and abandoned it. They appear to have come to the conclusion that, owing to the great trouble and expense in keeping the furnaces in repair, the system possessed no special advantage over the ordinary Siemens furnace. If I am not mistaken, however, the Steel Company of Scotland were using these furnaces for soft steel for ship plates, whereas, in the instances referred to, rail steel was being manufactured. This is an important differ-

ence, the temperature in the former case requiring to be much higher than in the latter, the carbon being less, and the metal, therefore, more infusible; consequently, the wear and tear and attendant expenses would be proportionately greater. Be that as it may, it is beyond dispute that this system has achieved a considerable measure of success abroad, which will probably increase, as modifications, such as I have referred to, are gradually effected to reduce wear and tear, and facilitate repairs.

We now come to the Ponsard furnace. It aims at combining the advantages of the Bessemer and open-hearth processes. The furnace is so arranged that, by giving it a half revolution on its oblique axis, the twyers with which it is supplied may be brought either beneath or above the surface of the bath metal. By these means the metal can be rapidly decarburized nearly entirely, as in the Bessemer converter, and then, by removing the twyers from beneath the metal, the final adjustment of the carbon can be made as in the Siemens process. The only difficulty experienced in working out this idea to a practical success appears to be the rapid destruction of the twyers. This obstacle is certainly a very great one, and it may possibly be found insurmountable.

It may here be remarked that some firms in France, and, indeed, in England, too, claim to be able to produce steel of any required composition and characteristics with equal exactness by the Bessemer process as by the Siemens. There can be but little doubt that much can be done in this way by the Bessemer process where the work is systematically and carefully carried on.

Notwithstanding the fact that phosphorus cannot be eliminated in the ordinary Bessemer converter, enormous quantities of steel have been made by this process, and within the last two or three years means have been devised by which this bugbear of steel makers has been overcome. I refer to what is known as the Thomas-Gilchrist or "basic" process.

In the ordinary Bessemer converter the lining is formed of ganister, a siliceous material. Now, silica has a greater affinity for oxide of iron than phosphoric acid has, consequently, so long as free silica is present phosphoric acid cannot remain in combination with oxide of iron; whilst, then, the lining of the converter was of silica, it is sufficiently obvious that phosphoric acid could never be eliminated.

You will at once say, why line the converter with this objectionable substance? The answer is easy—No substitute was known, and the reason why phosphoric acid was not removed was not generally understood.

This was the state of things when Messrs. Thomas & Gilchrist commenced their experiments. The object they had in view was to substitute for the ganister a basic material, such as lime. The difficulty they had to contend with was to obtain a lining which would hold together. After many failures and much patient labor, a material has been found which fulfills the necessary conditions. This material is magnesian limestone; by grinding it and mixing it with pitch, bricks can be formed, which, after burning, are very refractory. In lining the converter it was impossible to cement the bricks satisfactorily together; they generally get a good deal curved in baking, and fit badly together, and the cementing material is easily washed out by the molten metal. In order to get over this difficulty, the converters have been lined by running the material in, and then drying and heating in stoves the various pieces of which the converter is composed. This method has proved to be more successful.

From an enemy, by judicious treatment, we may be said to have converted phosphorus into a friend. In the acid process, it is essential that about 2 per cent. of silicon should be present, for it is, to a great extent, due to the presence of silicon, that the requisite high temperature can be obtained. In the basic process, the less silicon there is the better; because it destroys the lining by fluxing it away. Here it is that the phosphorus befriends us, for it, too, is capable of producing a high temperature by combining with oxygen; and that being the case, it becomes possible to work with about half the silicon necessary in the acid process, which practically means that we may employ a much lower grade of iron; for the lower the grade of iron, the smaller will be the amount of silicon in it.

So appreciated has this hitherto despised substance become, that it is actually the practice to put back into the blast furnace a great part of the slag from the converter, in order to increase the amount of phosphorus in the pig iron, subsequently to be converted into steel.

There is, however, a limit to the lowness of grade of iron which can be used, for, although the silicon decreases, the sulphur increases, and only about half the sulphur present in the pig iron can be removed in the converter. One-tenth per cent. of sulphur suffices to prevent steel from rolling in a sound condition. As I have already pointed out, the way to counteract the influence of sulphur is to employ manganese in sufficient quantity, but this is not without a drawback, for manganese is expensive.

In working out this process, much difficulty was at first experienced, owing to the mouth of the converter getting gobbed up, that is to say, stopped by projected slag. The basic slag, consisting as it does principally of lime, is very pasty. This inconvenience has been successfully got over by employing converters of the form shown on the diagram. It was predicted by many, that the slag and metal would be thrown out of the mouth of this form of converter; but that has not been the case, and it is not improbable that eventually this shaped vessel will be universally adopted for both the acid and the basic processes. Such is already the case at Messrs. Bolckow, Vaughan & Co.'s works, where, under the intelligent and persevering guidance of Mr. Windsor Richards, the basic process has first been made a commercial success in this country.

One word as regards the silicon, which, we have seen, is useful as a combustible in the Bessemer process. This substance produces both red and cold shortness in steel, which has to be worked, if present, in even so small a quantity as two-tenths per cent. But in the production of sound steel castings, it has been found to exert a very beneficial influence by preventing the metal from becoming honey-combed by escaping gases while solidifying. It exerts its influence by combining with oxygen, which would otherwise unite itself to carbon, and form a gaseous compound; the silica thus produced passes rapidly into the slag in combination with manganese, which is introduced at the same time as the silicon in an alloy containing them both.

In consequence of the extremely high temperature which we can command, either in the Bessemer or open-hearth processes, it is possible to obtain in a molten state metal practically free from carbon, or containing carbon to any required amount. It is sufficiently obvious that, having regard to the original and commonly understood meaning of the word steel, some other name should, strictly speaking, be applied to all metal manufactured by these processes, which cannot be hardened and tempered. In practice, however, there are many obstacles in the way of this being done, and it has become customary to designate by the term steel all the metal which has been produced in a molten condition by the Bessemer or open-hearth furnaces.

It thus has resulted that we speak of steel ships, steel boilers, and steel rails. The metal of which ship plates are made contains about $\frac{13}{100}$ths per cent. of carbon, that for boilers about $\frac{24}{100}$ths, while rails usually have about $\frac{4}{10}$ths. The first and the second could not be appreciably hardened, and the third is considerably below what would formerly have been considered steel.

Although, then, metal possessing the true characteristics of steel can be made by these processes, yet that which is ordinarily made is not steel, but a metal called into existence by our recently acquired power of obtaining an extremely high temperature.

This new metal, as we may fairly call it, has properties far excelling those of wrought iron, and it has only been a question of time to make this universally felt.

At the present moment new iron rails are things of the past, and wooden sleepers have begun to follow in their wake, it having become apparent to all that our new metal will be an economical substitute. So with ships, the wooden walls of old England are no more. Steel has not only supplemented wrought iron where it was used, but the wood also.

At present there is but one sound reason why steel should not universally replace iron with advantage, and that is,

that in some cases it is cheaper to employ iron. Statistics show us that the enormous quantities of steel now manufactured have but little, if at all, affected the production of wrought iron. It is, however, I am convinced, but a question of time. When the day comes, and every day brings us nearer to it, when steel will be manufactured as cheaply as iron, then will wrought iron be a thing of the past amongst the great civilized nations.

One word as regards the employment of steel made by these modern methods for cutlery. Cutlery manufacturers would tell you that it is useless for the purpose; nevertheless, on the Continent, it is very largely used, and in this country to a considerable extent. I do not hesitate to assert that, with suitable ores and proper care in the manufacture, steel well suited for cutlery can be made both in the open-hearth and the converter. The essential in the ore is that it should not contain phosphorus; with but a trace of phosphorus present, a good cutting edge could never be obtained.

I have endeavored to show you this evening in what progress has really consisted, and how it has been brought about. If we glance back for a moment, we see that the open-hearth processes embody the same principle as the first process by which steel was produced, viz., the mutual action of carburized iron and oxide of iron on one another, and the Bessemer process is, after all, though a splendid offspring, only the natural descendent of the finery process, the origin of which, as we have seen, was due to modifications in the primitive blast furnaces. There is perfect continuity throughout, and, after all, what more natural? Progress in the art of manufacturing steel has been the joint work of the scientific chemist and the engineer. As in the past, so in the future, success will depend upon these two elements working harmoniously together.

RIVET HOLES IN STEEL PLATES.

From "Engineering."

Our information respecting the relative effect of punching and drilling steel plates of different thicknesses has just received a valuable addition in the form of the results of an extensive series of experiments carried out under the direction of the Board of Trade, these results being embodied in a "Memorandum," by the engineer surveyor-in-chief, Mr. Thos. W. Trail, which has just been published for the use of the Board of Trade surveyors. The "Memorandum," which is signed by Mr. Thomas W. Trail, Mr. Thomas J. Richards, and Mr. Peter Samson, relates to the strength of steel plates and angles as ascertained by the application of tensile, bending, and bulging strains, &c., to the effect of different modes of forming rivet holes, to the strengths of different constructions of riveted joints, and to the efficiency of different modes of staying the flat surfaces of boilers made of steel plates; for the present, however, we propose to confine our attention to that section relating to the relative effects of punching and drilling rivet holes, leaving the other sections for subsequent notice.

The first series of experiments with which we propose now to deal were made to determine the relative effects of drilling, punching without annealing, and punching followed by annealing, and the plates experimented upon were of four different thicknesses, namely, $\frac{1}{4}$ in., $\frac{1}{2}$ in., $\frac{3}{4}$ in., and 1 in. The testing was all performed by Mr. Kirkaldy, and the specimens dealt were all of large size, being 12 in. in width at the portion where the holes were formed. The drilled samples were drilled by Mr. Kirkaldy, the diameters of the drilled holes being made to correspond with the diameters of the punched holes at their smaller ends, while the punched samples, and those which were punched and subsequently annealed, were prepared by Messrs. J. and G. Rennie, the punches and dies used being those ordinarily employed on their works. The plates were all sup-

plied by the Steel Company of Scotland, the steel being made by the Siemens-Martin process, and samples cut from two plates of each thickness being tested. The samples were, as we have said, 12 in. wide at the part where they were perforated; at the ends their width was increased, and these widened portions were each held between other steel plates by nine tightly fitting pins passing through bored holes, these pins being so arranged as to give a fair distribution of strain throughout the width of the sample. In the case of the ¼ in. and ½ in. plates, each sample had its central portion pierced by 12 holes .79 in. in diameter and 2 in. pitch, these holes being disposed in two rows, six in each, and the rows being 2 in. apart from center to center. In the case of the ¾ in. plates the samples cut from one plate had also the holes disposed as above described, while those from the other plate were pierced with eight holes 1.08 in. in diameter and 3 in. pitch, disposed in two rows, four in each, the rows being 3 in. apart from center to center. Lastly, in the case of the samples of 1-in. plate, the two drilled test pieces were pierced in the two modes adopted for the ¾-in. plates, while the punched, and the punched and annealed samples were all perforated in the same manner as the ¼ in. and ½-in. plates. In the case of the samples perforated with the holes 0.79 in. in diameter, 60.5 per cent. of the original area of the plate remained in each line of holes, while in the case of the specimens pierced with 1.08 in. holes, the metal remaining was 64 per cent. of the original area.

In the tables of results Mr. Kirkaldy gives the stresses "per square inch of gross area at holes," this perhaps somewhat ambiguous expression meaning the stresses per square inch of the original sectional areas of the specimen before the holes were formed. The average results are tabulated in the "Memorandum" as follows:

Specimens.	Ultimate stress per sq. inch of gross area at holes.			
	¼ in.	½ in.	¾ in.	1 in.
	tons.	tons.	tons.	tons.
Drilled	21.9	19.6	19.65	18.3
Punched	19.3	16.65	15.8	13.45
" and annealed.	20.15	18.55	18.7	17.8

This summary shows three principal facts very clearly, namely, first that the drilled specimens were decidedly superior to those which were punched; secondly, that the injury done by punching was to a very great extent removed by subsequent annealing; and third, that the difference in strength of the drilled and punched specimens was materially increased with an increase in the thickness of the plate, or in other words that the thicker the plates the greater was the injury done by punching.

Although, however, the mode of comparison adopted in the above table has certain conveniences, yet it is less useful for general purposes than one founded on the stresses on the sections of metal left between the holes. These stresses have been calculated from Mr. Kirkaldy's figures by the authors of the "Memorandum," and we give below the table containing the summarized results. In giving this we should state that in calculating the net area of plate the diameter of the punched holes has been taken as the diameter at the *small* end; in other words, it has been taken as the diameter of the rivets which the punched holes would accommodate. This mode of taking the diameter of the holes naturally tells against the thicker plates, as the thicker the plate is the greater is the effect of the taper of the holes made by the punch in reducing the section. This must be borne in mind in examining the results recorded. The "Memorandum" before us, however, does not afford the data for enabling us to give to the effect of the taper of the punched holes any absolute value for comparison. The following is the table:

Specimens.	Mean stress per square inch of net section between holes.			
	¼ in.	½ in.	¾ in.	1 in.
	tons.	tons.	tons.	tons.
Drilled	36.21	32.44	31.64	29.42
Punched	31.94	27.53	24.6	21.02
" and annealed.	33.41	30.75	30.05	27.82
Solid plates	31.65	29.15	29.7	27.7

The results shown in this table, as far as the general relative effect of drilling and punching and the influence of thickness of plate are concerned, are identical with those to be derived from the table

previously given; but there is in addition another important feature shown, namely, the effect of the perforations in increasing the power of resistance of the metal left between the drilled holes, as compared with an unperforated plate. Thus, with drilled holes, this gain in strength amounted in the case of the $\frac{1}{4}$ in. and $\frac{1}{2}$ in. plates to 13.8 and 11.1 per cent. respectively, while for the $\frac{3}{4}$ in. plates it was 6.4 per cent., and for the 1 in. plate 6.1 per cent. This increase of ultimate strength, due to a specimen being reduced to its smallest section only for a small length, has for some time been a well-known fact, and it appears to be the more marked the softer or more ductile the material is. It may be remarked here that recent experiments on riveted joints in steel plates have shown that to secure maximum strength, the proportion of rivet area to net area of plate between rivet holes must be considerably greater than in iron, and judging from the facts that we have just been recording, it appears probable that this result is, in a considerable measure, due to the access of strength to the portions of the plate left between the rivet holes, this gain of strength necessitating an increase of rivet area to balance it, and to secure a maximum strength of joint. The sudden variation in this gain of strength, which accompanies the increase of the thickness of the plates from $\frac{1}{2}$ in. to $\frac{3}{4}$ in., is very singular and difficult to account for without further experimental data. In the case of the plates which were punched and subsequently annealed, there is also in the case of the $\frac{1}{4}$ in. and $\frac{1}{2}$ in. plates a marked gain of strength between the holes, while there is also a gain, but a very small one, in the $\frac{3}{4}$ in. and 1 in. samples. With the punched holes, not annealed, there is in the case of the $\frac{1}{4}$ in. plates a gain of 1 per cent. in the strength between the holes; but with the other thicknesses there is a decided loss, this loss amounting in the case of the 1 in. plates to as much as 24.2 per cent. In fact these experiments show very strongly how greatly thick plates are injured by punching, but they also show with equal clearness how the injury thus caused is almost entirely removed by proper annealing. It is however essential that the annealing should be carefully and thoroughly done.

Another point shown by the table last given is the superior strength of thin as compared with thick steel plates, even when unperforated, an exception to the regular gradation of strength being, however, shown by the $\frac{1}{2}$ in. and $\frac{3}{4}$ in., the latter of which is somewhat stronger than the former. It would be of considerable interest to know the sizes of the ingots from which the plates experimented upon were rolled. It is now very generally admitted that to obtain the best results with steel plates, the ingots used must have dimensions which are large multiples of the final thickness of the plate, and the use of exceptionally large ingots for plate making has long been an important feature in the very successful practice of Mr. F. W. Webb, at the London and Northwestern Railway Works at Crewe. It follows from this fact that to get equal final results, the thicker the plate to be produced the larger the ingot should be so as to secure the necessary amount of "work" on the metal during the process of manufacture. Bearing this fact in mind it would, as we have said, be of much interest to know to what extent the strength of the plates tested for the Board of Trade was affected by the relation between the final thicknesses of these plates and the dimensions of the original ingots, although judging from other recorded facts the superior tensile strength of the $\frac{1}{4}$ in. plates appears to have been largely due to their greater hardness, as we shall see presently.

Another matter of importance brought out by the experiments under notice is the relative elongation of the punched and drilled holes before fracture occurred. We subjoin a table which summarizes the mean results obtained, and it will be observed that the figures there recorded show for the $\frac{1}{2}$ in. and $\frac{3}{4}$ in. plates a ductility considerably superior to that of either the $\frac{1}{4}$ in. or the 1 in. plates. In the "Memorandum" before us particulars are given of the testing of unperforated samples of plates, and in these the same feature is also to be noticed, the ultimate extensions in 10 in. length of the $\frac{1}{4}$ in., $\frac{1}{2}$ in., $\frac{3}{4}$ in. and 1 in. plates being respectively 17.2, 26.9, 26.0 and 24.4 per cent. The $\frac{1}{4}$ in. plates thus appear to have been of considerably

harder quality than the others. The table just referred to is as follows:

Specimens.	Elongation of holes at ultimate stress.			
	$\frac{1}{4}$ in.	$\frac{1}{2}$ in.	$\frac{3}{4}$ in.	1 in.
	pr.ct.	pr.ct.	pr.ct.	pr.ct.
Drilled	24.3	37.0	37.6	33.5
Punched	11.7	18.5	11.1	4.3
" and annealed	27.1	35.1	33.0	29.8

It will be noticed that in the case of the $\frac{1}{4}$ in. plates the punched and annealed samples actually gave a higher elongation than the drilled specimens, the hardness of the plates apparently having been affected by the annealing. Respecting the figures above recorded the "Memorandum" states: "From the results of the experiments there appears to be no doubt that in the event of the stress on either a ship or steam boiler constructed of this mild steel approaching a dangerous limit, warning would be given by leakage at the rivet holes if the holes were drilled, or the plates properly annealed after punching. The elongation of the punched holes has been shown to be so much less than of the drilled holes or the punched holes when the plates are afterwards annealed, and the punched specimens break so suddenly, that it is doubtful if warning would be given under similar circumstances." With these remarks we entirely agree.

In addition to the experiments with which we have dealt above, the "Memorandum" before us contains particulars of another series, in which the specimens included not only drilled, punched, and punched and annealed samples, but also samples the holes in which had been punched of less than the required diameter and subsequently enlarged by boring. The plates, as in the previous series, were supplied by the Steel Company of Scotland, while the specimens were prepared free of cost by Mr. Halket, the manager of the Glengall Iron Works, Milwall. Thirty-two specimens were prepared in all, namely, eight of each thickness of $\frac{1}{4}$ in., $\frac{1}{2}$ in., $\frac{3}{4}$ in. and 1 in., and one specimen of each thickness was drilled, two punched and not annealed, two punched and annealed, two punched small and bored to size, and one left unperforated. For the different thicknesses the widths of the samples were: For the $\frac{1}{4}$ in. plates, perforated 1.65 in., unperforated 1.17 in.; for the $\frac{1}{2}$ in. plates, perforated 3.32 in., unperforated 2.32 in.; for the $\frac{3}{4}$ in. plates, perforated 4.95 in., unperforated 3.44 in.; and for the 1 in. plates, perforated 6.66 in. and 6.54 in., and unperforated 4.66 in. The holes in each case had a diameter equal to the thickness of the plates, and two holes were placed in the width of the strip. In the case of the holes first punched and then bored to size, the following diameters were adopted for the punched holes:

Thickness of plate.	Diameter of holes as punched.	Diameter of holes when bored.
in.	in.	in.
$\frac{1}{4}$	$\frac{13}{64}$	$\frac{1}{4}$
$\frac{1}{2}$	$\frac{13}{32}$	$\frac{1}{2}$
$\frac{3}{4}$	$\frac{5}{8}$	$\frac{3}{4}$
1	$\frac{13}{16}$	1

As is pointed out by the authors of the "Memorandum," these proportions, although probably fairly representing ordinary practice, are scarcely such as it is desirable to adopt in order to secure the best results with this mode of forming rivet holes. In punching plates for boilers, absolute accuracy cannot of course be insured, and when the plates are brought together it will in many cases be found that unless a larger allowance for boring has been made than the above table shows, it will be impossible to secure both perfectly fair holes, and to insure that each punched hole has a sufficient amount of metal removed from it around its entire circumference. In the case of the specimens for testing, however, this argument of course does not apply. The results obtained with the specimens above described are summarized in the following table:

Specimens.	Ultimate stress per sq. inch of net section.			
	$\frac{1}{4}$ in.	$\frac{1}{2}$ in.	$\frac{3}{4}$ in.	1 in.
	tons.	tons.	tons.	tons.
Punched	28.33	25.33	22.94	21.26
" and annealed	31.6	29.39	29.31	29.12
" small and bored to size	31.23	30.86	28.81	29.15
Drilled	31.46	31.37	30.23	28.43
Unperforated	30.17	29.69	27.84	28.17

It will be seen from the above table that as far as the ultimate strength is concerned, the boring out appears to be as effective as subsequent annealing in removing the injury due to punching, there being in fact little to choose between the drilled, punched and annealed, and punched and bored-out specimens. When, however, the ductility of the material is considered it will be found that the comparative results are somewhat different, as the subjoined table shows:

Specimens.	Elongation of holes at Ultimate stress.			
	¼ in.	½ in.	⅝ in.	1 in.
	pr.ct.	pr.ct.	pr.ct.	pr.ct.
Punched..............	9.5	12.0	10.6	3.0
" and annealed.	36.5	43.0	35.3	26.0
" small and bored to size	22.0	28.5	22.6	25.0
Drilled..............	32.0	44.0	32.0	44.0

The results recorded in this table are important, for they show clearly that the plan of punching holes small and then boring them out is decidedly inferior not only to drilling but also to punching and subsequent annealing. It is possible, however, that this difference might have been removed had the quantity bored out been greater. As bearing on this point we may add that the "Memorandum" gives particulars of some experiments on counter sunk holes such as are used on the outer strakes of the hulls of vessels, the countersinking being continued right through the plate. In the case of these specimens it was found that the ultimate strength was practically the same whether the holes were wholly drilled or whether they were punched and subsequently countersunk, but in the matter of extension before fracture there was a decided advantage in favor of the holes wholly drilled.

The experiments recorded in the "Memorandum" bring out in a very striking light the effect of perforations in modifying the ultimate extension of a sample under strain, this extension being principally localized to the neighborhood of the holes. Thus in the case of the ¾ in. plate (which is a fair specimen of the average results) a 10 in. length perforated by punching elongated but 0.8 per cent. under a strain of 50,000 lbs. per square inch of net section, while under the same strain the punched and annealed specimen elongated 1.55 per cent.; the punched and bored 1.05 per cent.; the drilled 1.5 per cent.; and the unperforated 4.6 per cent. Under a strain of 60,000 lbs. per square inch of net section the punched specimen broke, and the elongations for the others became: punched and annealed 3.85 per cent.; punched and bored 3.5 per cent.; drilled 3.9 per per cent.; and unperforated 12.4 per cent. As the authors of the "Memorandum" point out, these figures show that any attempt to determine the strain upon a boiler shell when under pressure, by measuring the circumferential elongation of the shell plates, must be open to great doubt, it being difficult, if not impossible, to make the necessary allowance for the localization of the extensions at the lines of perforation. Altogether the "Memorandum" we have been considering affords much very useful information, and we propose in another article to deal with some of the other branches of experimental inquiry, of which it records the results.

THE PHENOMENA OF EXPLOSION

From "The Engineer."

In the present day explosions may be said to play a large part in the world's business and pleasure. Gas engines depend on explosions for their action. Whenever a shaft has to be sunk, a quarry opened, or a tunnel driven, recourse is had to gunpowder or dynamite. We need say nothing of great guns. As for small arms, the sportsman is absolutely dependent on the explosive power of gunpowder for the killing of game. At every turn we find explosions either purposely induced by elaborate contrivance; or intruding themselves on our

notice unsolicited, and, indeed, after every precaution has apparently been taken to avoid their recurrence. It can not be said that the phenomena of explosion are unfamiliar; and considering all the circumstances, it is not a little strange that hardly any sufficient thought has been given to the phenomena by scientific men, and that we may seek in vain for trustworthy and complete theory of the action of explosives. We have no intention of attempting to supply what is wanting. We write now in the hope that those who have the time and the means, and the requisite skill, will devote their attention to the subject, investigate the phenomena of explosion, and give us some definite information, which can hardly fail to prove useful. To this end we propose here to place before our readers certain considerations which lead up to queries, which may or may not admit of being answered.

When a mixture of hydrogen and oxygen is ignited, an explosion takes place, and water results. Two atoms of hydrogen H—O—H combine to form water. Two volumes of hydrogen combine with one volume of oxygen to form two volumes of aqueous vapor. If more than the right proportion of either gas be present, an explosion will nevertheless take place, but there will be left just as much of either gas as was present in excess. Thus if 100 measures of hydrogen were mixed with 80 measures of oxygen, there would, after explosion, be 30 measures of oxygen left, quite pure—as far at least as hydrogen is concerned. If we ask what takes place during explosion, we can obtain no answer, save that there is, first, a great dilation of the gas attended with the evolution of light and heat, subsequently a reduction of pressure, and, lastly, a very great reduction of pressure, as the steam formed in the first instance is condensed. It would appear from what we have said that it is impossible to make hydrogen and oxygen combine to form water without an explosion. This idea is supported by the fact that the well-known singing noise made when hydrogen burns in air is attributed to the rapid succession of a multitude of minute explosions. On the other hand, however, there is some reason to believe that the mixture can be made to flame quietly without any approach to an explosion, as, for example, in a Bunsen burner, or, indeed, in any ordinary gas jet; and it should be borne in mind that in the laboratory the combination of the two gases is generally effected by the electric spark. When gun cotton is inflamed a somewhat complex chemical reaction takes place, akin in some respects to that occurring when gunpowder is burned. But gun cotton presents a peculiarity of very great importance, namely, that if ignited in one way it will burn rapidly away without exploding, whereas if it be ignited in another way it explodes with great violence. Dynamite behaves in much the same manner, and can at will be made either to explode or to burn quietly. The importance of these facts will be seen when we ask is it not possible that many other things besides dynamite and gun cotton may or not be explosive according to the way in which they are ignited? Fine flour dust or stive can, there is every reason to believe, be burned quietly or made to explode with great violence according to circumstances; and it is not impossible that the same statement may be quite true of mixtures of air and coal gas in mines or gas mains.

As to the conditions determining explosion or not in gun cotton, to which for the moment we may confine our attention, they are well known. A cake of wet gun cotton can hardly be induced even to burn; but if a percussion cap be caused to detonate in the cake, the whole will explode with just as much violence as though the cotton were dry. Before we can attempt to arrive at an explanation of the cause of this somewhat puzzling phenomenon, it is necessary to know why gun cotton explodes at all. We have already referred to explosions of mixtures of hydrogen and oxygen, and we have done this advisedly, because such explosions are typical. With certain comparatively unimportant exceptions, all explosions are caused by the combination of oxygen with something else. In gunpowder we have the oxygen of the nitrate of potash uniting with the charcoal and sulphur. The formula of gun cotton is probably $C_{36}H_{21}O_{30}NO_4$; what precisely takes place during explosion is not certainly known, but we have at all events hydrogen and carbon ready

to form a new combination with the oxygen. The basis of gunpowder, gun cotton and dynamite—nitroglycerine—is nitric acid, $NO_2\ H_6$, and nitric acid gives explosive vitality to its compounds solely by virtue of the ease with which it gives up oxygen; in fact nitric acid is, broadly stated, a very unstable compound of oxygen and nitrogen. It is the most easily decomposed of all the acids, and cannot be kept pure in the sun's rays, the actinic rays causing it to give off oxygen. It is accordingly one of the most powerful oxidizing agents known. Powdered charcoal will burst into flame if a little strong nitric acid be dropped on it, and many experiments are well known to every student of chemistry proving the same thing. When nitric acid is employed to produce an explosive, it appears that nitric peroxide NO_2 is substituted for an equivalent of hydrogen, and NO_2 is an excessively unstable compound, giving up its oxygen on the smallest provocation. We have stated that there are certain comparatively unimportant exceptions to the rule that oxygen is always present in explosions. As one exception we may refer to chlorine, which is competent to play much the same part as oxygen, and which enters into the composition of some of the most unstable chemical compounds known. We may put these on one side, however, and turn now to what are known as fulminates. One of these is fulminating mercury $2(HgO)$, Cy_2O_3, another is fulminate of silver $2(AgO)$, Cy_2O_3. In both these we have again nitric acid present as the oxidizing agent. The first is readily caused to explode either by heating it or striking it. It is, however, a stable compound when compared with fulminate of silver, which can be exploded by touching it with any hard substance. We may contrast both with another detonating material, namely, fulminating powder, composed of three parts of niter, two of carbonate of potash, and one of sulphur, intimately mixed and dried. If this powder be touched with a hot iron it will burn away slowly; indeed, it is difficult to cause it to burn at all. If a small spoonfull be placed on a sheet of tin over a slow fire, the powder as it heats will gradually assume a pasty condition, then a lambent blue flame will begin to burn on its surface, and then the whole explodes with a report, the tremendous noise of which is out of all proportion to the quantity of powder used, and the explosion is strangely enough practically harmless, and incapable of displacing even a light sheet of tin. We have not been able to find a reference to this powder, giving any information of use, in any work on chemistry. It is mentioned in some books, but that is all. Chloride of nitrogen and iodide of nitrogen are violently explosive. They contain, however, neither oxygen nor carbon, and their effects seem to be due to the sudden liberation of a very large quantity of nitrogen from a very small quantity of the powder. Again, all chlorates—as, for example, chlorate of potash—part with their oxygen more readily than nitrogen, and this is one reason why chlorate of potash is more powerful as an explosive ingredient than nitrate of potash.

Now, what we have said suffices, we think, to prove that combinations exist which can be caused to assume new relations, and to form new combinations either quietly or with explosive violence; and we have further shown that mere mechanical concussion will cause explosion without the application of heat in any shape or form. Again, there is one substance certainly, namely, the fulminating powder, to which we have just referred, which can be made to detonate only by somewhat long-continued heating. We have thus certain forms of matter requiring diverse conditions to bring about identical results. For example, wet gun cotton will not explode, no matter how great the heat to which it is exposed. Heat alone is powerless in this case to bring about the required result; but heat and percussion together, that is to say heat, and what we may call mechanical shock, will induce an explosion at once. The same statement holds true of dynamite. Neither percussion nor heat alone will make it explode, but the combination of the two, as when a small quantity of fulminate of mercury is fired in contact with it, has the desired effect. Thus, then, as we have said, explosions result in some cases from the application of heat alone; in others from the application of percussion alone; and in yet other cases from the application of both

heat and percussion alone; and we have also seen that forms of matter which under ordinary conditions burn slowly or quickly away, can under other conditions be made to explode with awful violence. May we not now ask, are we at all certain that we can identify all the forms of matter which certainly cannot be made to explode under the combined influences of heat and percussion? If we cannot, we may, perhaps, have not far beyond our reach the key to the cause of such events as the flour mill explosions at Minneapolis, and those which occur, alas, too frequently, in our coal mines. If coal or flour dust hangs in the air we have oxygen and carbon in very close proximity. The nitrogen of the atmosphere plays only the part of a diluent; the oxygen has no affinity for it. Let a flame be applied, the oxygen and the coal dust or flour dust may combine quietly and produce a flame. But it is quite as certain that these combinations may produce an explosion, and what is required to bring about the explosion is apparently percussive action of some kind. No doubt the Minneapolis explosions followed each other because shocks followed each other. In the same way it is by no means impossible that a shot fired in a coal mine may play nearly the same part with the mixture of air and gas present as the percussion cap does in a cake of wet gun cotton. When oxygen and hydrogen are exploded in an eudiometer, the electric spark supplies the equivalent of the percussive action necessary to produce that instantaneous combustion, which causes so much mischief when it is effected on a large scale. We might pursue this section of our subject and go on heaping up illustrations of the effect of percussive action on what are known as unstaple compounds, bnt it is not, we think, necessary. The lesson to be drawn from what we have written is that it is advisable to carry out some experiments to ascertain the effect of percussion on compounds believed to be tolerably staple. It may, for instance, be shown, perhaps, that a mixture of coal gas and air which cannot be exploded in the ordinary way may be caused to explode by a detonator. The same experiment may be tried with an atmosphere charged with coal dust or stive. It is obvious that if explosion can be caused in the way suggested something very important in the management of coal mines will have been learned. The study of this department of molecular physics ought not to be delayed any longer.

HYDROGEN AND CARBONIC OXIDE IN IRON AND STEEL.*

By MR. JOHN PARRY, Ebbw Vale.

From "Iron."

In 1867 Professor Graham published his remarkable experiments showing that various metals were capable of absorbing many times their own volumes of H and CO and evolving the same when heated *in vacuo*. As regards iron, Graham found, first, that 46 grammes of clean iron wire, sp. gr. 7.80, heated two hours, evolved 46.85 c.c. gas; one volume of iron had therefore discharged 7.94 volumes gas, of which about two-thirds was carbonic oxide. (2) Another sample gave 7.27 volumes gas, containing about 15 per cent. carbonic acid, the remainder being principally carbonic oxide with hydrogen and a trace of hydrocarbon. (3) The exhausted iron wire was exposed at a red heat to the action of carbonic oxide, and was found to have absorbed 4.15 times its own volume of the gas. Graham states that wrought iron is a metal not likely to contain small quantities of carbon and oxygen in chemical union with iron, and the gas extracted may be partly due to a reaction of these elements upon each other at a red heat. In another experiment, 32 grammes of iron wire, measuring 4.1 c.c., heated in an exhausted glass tube to exclude the idea of the

* Read at the Spring Meeting of the Iron and Steel Institute.

conceivable permeability of the porcelain tube previously used, gave in one hour 29.8 c.c., of which 4.44 per cent. was carbonic acid, the remainder being principally carbonic oxide and hydrogen with a trace of hydrocarbon. The metal did not yet appear to be quite exhausted, and in another experiment the extraction of the natural gas was pushed to a greater degree of exhaustion. Thirty-nine grammes thus treated gave in two hours 45 c.c.; in the third hour, 10.85; in the fourth and fifth, 5.65; in the sixth, 0.9; and in the seventh, 0.7 c.c. gas. The iron now appeared nearly exhausted, after the extraction of 63.1 c.c., or 12.55 times the volume of iron used. The mass of exhausted iron wire remaining after the last experiment was heated to redness in hydrogen and cooled gradually in the same gas, and the metal was then freely exposed to air to get rid of any loosely attached hyd ogen. Exhausted again by the Sprengel air pump at a low red heat, the iron gave 2½ c. c. in one hour, but the greater portion came off in the first ten minutes. Analysis showed hydrogen, 2.3; carbonic oxide, 0.2. The iron had therefore absorbed 0.46 its own volume of hydrogen, and it also had become white like galvanized iron. Another experiment gave 0.43 volume of hydrogen absorbed. The same specimen was then treated in carbonic oxide. The gas absorbed amounted to 23.08 c. c., and of this 20.76 proved to be carbonic oxide. Pure iron, then, is capable of taking up at a low red heat 4.15 times its volume of this gas. The iron remained soft, and did not harden on heating and sudden cooling in water; in short, it was altogether unchanged. Graham remarks that the relations of the metal iron to carbonic oxide appear to be altogether peculiar. The intervention of carbonic oxide with charcoal in the process of cementation has long been recognized. The decomposing action of the charcoal has been supposed to be exercised only at the external surface of the metal. The process is not confined to the surface of the metal, but may occur throughout the substance in consequence of the previous penetration of the metal by carbonic oxide; and it would appear that the diffused action of the gas is the proper means of distributing the carbon throughout the mass of iron. Graham having thus first proved the existence of gas in iron, it was thought that a more extended series of experiments on the various kinds of crude iron, steel, &c., might lead to useful results; that it was desirable to accurately determine the quantity and composition of the gases likely to be present, such information being rendered more valuable from the fact that the history of the manufacture of the sample tested could be readily obtained. It was, however, found that the experiments entailed great difficulties; much time was lost ere reliable results could be obtained; and even now, after nearly six years' work, the author is of opinion that this important subject is yet far from exhausted. Quite recently the matter has again attracted attention, and several workers have contributed valuable information on the points investigated by Graham. The author proposes giving as briefly as possible the results obtained by other workers, concluding with a summary of his own researches. Müller obtained by his well-known methods the following results:

	Gas per cent.	Composition of Gas.		
		H.	N.	CO.
1. Bessemer steel rail..........	48	90.3	9.71	0.00
2. Spring steel...	21	81.9	18.50	0.00
3. Steel before addition of spiegel..........	60	88.8	10.00	0.70
4. Steel after do.	45	77.0	23.3	0.00
5. " rail " .	29	76.7	26.9	0.00
6. " before " .	44	80.4	17.7	1.30
7. " rail " .	51	78.1	20.5	0.90
8. Soft steel.....	16.5	68.8	30.8	0.00
9. Siemens-Martin steel......	25.0	67.0	30.9	2.20
10. Bessemer steel, ingot........	17.0	92.4	5.3	1.40
11. Same forged..	5.5	73.4	25.1	1.30
12. Blistered Bessemer steel, forged.......	5.0	52.9	48.5	0.00
13. " rolled....	7.3	54.9	45.2	—
14. Bessemer pig-iron.........	15.0	86.5	9.2	4.3
15. " " .	35.0	83.3	14.0	2.5
17. " " .	28.0	81.1	14.8	4.1

This table shows that hydrogen in considerable proportions exists in all kinds of steel. These results are confirmed

by the more recent determinations of Messrs. E. W. Richards and Stead, which are as follows:

	Steel Ingot.				Hammered Iron.	Cast Iron.
	1.	2.	3.	2.	5.	6.
Carbon......	0.330	0.450	0.170	0.42	0.050	3.65
Manganese ..	0.690	0.400	0.890	1.08	0.700	0.60
Silicon.	0.100	0.040	0.090	1.00	0.150	2.53

	Metal removed.	Gas evolved	Composition of Gas.				
			H.	N.	CO.	CO_2.	O.
No. 1.	28.3	15.6	86.62	13.29	0.32	none	0.37
No. 2.	65.0	48.0	85.35	14.65	—	—	—
No. 3.	42.0	10.5	87.21	11.15	1.64	—	—
No. 4.	41.6	8.66	67.1	30.30	1.60	—	—
No. 5.	12.25	3.46	30.62	69.38	—	—	—
No. 6.	19.60	4.80	52.5	44.90	—	—	—

Mr. Richards states that some if not all the H might have been obtained from the water. No. 4 was drilled with a blunt drill under water; gas obtained, 17.32 cubic inches; composition, H 88.7, N. 10.3. Steel ingots were subsequently drilled in a bath of mercury; the gas obtained was very minute in quantity and proved to be hydrogen. Previous to the publication of the experiments of Messrs. Müller and Richards, the author was under the impression that the presence of hydrogen in steel was rather advantageous than otherwise, the hydrogen serving to neutralize the oxidation which is apt to occur on heating steel in common reverberatory furnaces, and that the bubbles, &c., in steel, were due solely to the carbonic oxide (considering the latter as being insoluble in steel); while, on the contrary, hydrogen is absorbed at a temperature much below the fusing point of steel. It is plainly indicated that the presence of gas in steel cannot be ignored, and the quality or fitness of steel for certain purposes may be determined by the amount of gas it contains. These experiments have reference only to the quantity of uncombined gas—*i. e.*, gas issuing from steel already overcharged, thereby forming bubbles and tending to the production of unsound castings.* It is manifestly necessary to determine the total quantity of gas both combined and uncombined. As regards Bessemer steel, the determination of the absolute quantity becomes of great importance.

Messrs. L. Troost and P. Hautfeuille (*Compt. Rend.*, 482-485, 562-566, 1873), speaking of the gases existing in metals, state that molten iron and steel possess the property of dissolving gases which they evolve in a part as the temperature sinks. The disengagement of gas which is observed in making large castings and in other metallurgical operations is not due to the above cause alone, inasmuch as the phenomena can be produced under circumstances in which the variations of temperature are too slight to affect appreciably the solubility of the gases; and, moreover, the disengagement of gas is attended by changes in the composition of the metal operated upon. Cast iron kept in fusion in a porcelain tube under reduced pressure continued to evolve gas for three days. The same metal fused in an atmosphere of carbonic oxide or hydrogen behaved as in a partial vacuum. The gas given off was in all cases carbonic oxide, and the production of this gas was found to be due to the action of the fused metal upon the porcelain, the metal becoming gradually richer in silicon and poorer in carbon, until in some cases the proportion of silicon amounted to 8 per cent. Messrs. Troost and Hautefeuille made the following experiments with cast iron

* That the formation of honeycomb in steel is due to the presence of uncombined gases is well explained in a recent article in the *Engineer*, and preventive methods are given. 1. Dr. Muller assumes that hydrogen is the primary cause of bubbles, and that it is derived from the moisture in the air blown in, and proposes drying the latter by passing it through burnt lime. 2 To eliminate hydrogen by blowing in CO, which displaces the soluble hydrogen. Carbonic oxide, he says, is insoluble in molten steel. The mechanical or compression methods are also discussed, and it is explained that by certain methods, if the pressure be not sufficient, the center of the ingot is a mass of cavities. The author thinks with the writer that, on the whole, what he termed the chemical method is the best. Perfectly sound castings of nickel and copper are made by means of some chemical reagent. To nickel, phosphorus is added, and presumably also to copper. There seems no reason why a similar process should not be applied to steel. We are aware that to some extent this has already been done by adding silicious pig to the steel, a slag is thus formed and less gas generated. Unfortunately, from causes well understood, this cannot be efficiently done without leaving an injurious excess of silicon. A slag-forming substance, neutral in its effects on steel is required.

containing 1.21 silicon and 5.32 carbon, after 48 hours' heating in a porcelain tube:

Iron contained......	0.87	silicon	5.32	carbon
24 hours in silicious crucible....	1.07	"	3.90	"
Globule imbedded in crucible..........	3.40	"	—	"
Cast steel containing.	0.10	"	1.54	"
24 hours fusion in Hessian crucible..	0.26	"	0.74	"
2 hours fusion in silicious crucible....	0.80	"	0.70	"

These experiments show that at temperatures above the melting point of cast iron carbide of iron reduces silica. Hence to avoid the introduction of silicon it is necessary to fuse in vessels of lime or magnesia. They further state that these reactions must go on to some extent in the blast furnace and increase the proportion of silicon in the metal produced, but this is not the principal cause. The action of carbide of iron on silica is slow, more especially when highly basic slags are present. The chief cause lies in the action of alkaline metals, which are always present in silicates. A mixture of potassium, carbonate, carbon and iron filings fused together gave cast iron containing 5.16 per cent. silicon and 2.94 per cent. carbon. Cast iron highly heated in a carbon boat in an atmosphere of hydrogen undergoes tranquil fusion; no gas is disengaged, but after it has remained some time in the gas, if the pressure of hydrogen be rapidly diminished, the disengagement of gas is rendered evident by the projection of metallic globules and particles of graphite. If the temperature be suddenly lowered, the metal solidifies during the disengagement of gas, leaving a rough surface. About 500 grammes cast iron heated 190 hours, temperature 800, gave 16.7 c. c. gas, containing CO_2 0.6, Co 2.8, H 12.3, N 1.0; the greater part of the CO, in the first few hours; hydrogen is more forcibly retained. The same iron heated 48 hours in carbonic oxide absorbed 14.7 c. c., gave 1½ c. c. hydrogen, and took 170 hours heating to get this amount of gas. The same sample heated 48 hours in hydrogen absorbed 4.40 hydrogen.* To ascertain the effect of different proportions of carbon in the metal on the solubility of the gases, the following experiments were made:

500 grammes cast steel heated *in vacuo* evolved:

CO_2.	CO.	H.	N.	
0.05	1.4	0.5	0.25	=2.2 c.c.
500 grammes soft iron—				
2.20	10.80	4.4	1.10	=18.5 c.c.

These cylinders were heated up to 800°, first in hydrogen, and then in carbonic oxide, and exhausted as before.

	CO_2	Co.	H.	N.	C.C.
Cast steel 1	0.00	0.90	6.4	0.5	= 7.8 in hydrogen.
" 2	"	2.00	0.8	0.4	= 3.2 in carbonic oxide.
Soft iron 1	"	0.60	1.00	0 3	= 13 9 in hydrogen.
" 2	"	13.70	0.2	0 1	= 14.0 in carbonic oxide.

Steel retains the last traces of hydrogen much more forcibly than cast iron, notwithstanding that when saturated with the gas it gives off a portion at the ordinary temperature like palladium. Soft iron retains carbonic oxide more forcibly than it retains hydrogen, contrary to what is observed with cast iron and steel.

Simultaneously with Messrs. Troost and Hautfeuille's researches, the author was engaged in determining the gases in iron, &c., according to the method of Graham, with such precautions and modifications of the apparatus as from time to time suggested themselves. In the first series of experiments glass tubes only were used, which only bear a dull red heat. At a higher temperature they collapsed.

	Hours.	c.c.		c.c. gas.
Heated *in vacuo*,	3	1	spiegeleisen discharged	2
" "	6½	1	white pig iron discharged	2
" "	2	1	grey iron discharged	21
" "	2	1	steel discharged	13
" "	2	1	wrought iron discharged	21

of the following composition per cent:

	CO_2.	CO.	O.	H.	N.
Spiegeleisen(clean lumps...... ..	0.942	17.87	0.00	81.05	—
White cast iron..	6.800	2.32	"	84.00	6.88
Grey............	1.600	5.20	"	89.70	3.25
Steel clean drillings..........	16.550	24.352	"	52.01	6.488
Wrought iron bar.	9.92	34.262	"	54.10	1.718

A nearly but not quite perfect vacuum was obtained in the time given. Noting

* Carbonic oxide is much less soluble in iron than hydrogen.

this, it was determined to expose the metal in a good double glazed, double cased, porcelain tube. The tubes used were previously heated *in vacuo*, to remove any natural gas which might possibly be present, to the highest heat (nearly sufficient for the fusion of gray iron) the tube would bear. At this temperature it was found impossible to maintain a good vacuum; the metal continued to evolve gas for a few days, in one instance even after seven days' continuous heating. In the first stage, at a dull red heat gas was evolved freely for about six hours, when it almost ceased. At a bright red it was again rapidly given off for about twelve hours. The iron now appeared nearly exhausted, but an increase of heat had the effect of again starting the flow of gas, and this continued up to the highest heat attainable.

A vacuum can always be formed by lowering the temperature below the point at which the gas is being evolved. Grey iron heated for 165 hours gave 205 times its own volume of hydrogen and 135 times its own volume of carbonic oxide. During 128 hours the proportions of hydrogen and carbonic oxide were as 1 : .90; during the last 36 hours, 1 : .213. Heated in hydrogen, the exhausted iron absorbed only 20 times its volume of hydrogen. Heated in carbonic oxide, no absorption took place.* The gas, after contact with the wrought iron at a red heat, on being examined contained, in one instance, 4½ per cent. of CO_2, and in another 6.00. Bessemer steel analysis—Silicon, 0.080; carbon, 0.35; manganese, 0.72; and 1.02; per cent. of magnetic oxide of iron;† oxygen, 0.281 per cent. Of the oxide of iron obtained, a part equal to 0.26 per cent. proved to be easily soluble in hydrochloric acid. The remaining 0.76 per cent. was insoluble, but proved to be oxide of iron with a trace of manganese. A portion of the same sample oxidized by heating for a short time in the muffle was found to contain oxide of iron, soluble 2.6 per cent.; insoluble, 2.0; total oxygen, 1.26 per cent. Ten grammes of the steel heated *in vacuo* (temperature about the fusing point of copper) gave,

	Gas.		CO_2	CO.	Inflammable Gas, H &c.	
1st 24 h'rs	45.0	cont'ni'g	2.58	67.74	29.68	pr. ct.
2d 24 h'rs	41.0	"	0.66	41.80	57.54	"
3d 12 h'rs	5.0	"	1.44	8.39	90.07	"
T'l 60 h'rs	910 c. c.					

Sp. gr. of steel, 7.75. One cubic inch of steel, therefore, discharged 70½ cubic inches of gas. The sample of Bessemer steel previously tested contained more hydrogen. The steel which had been exhausted was heated in an atmosphere of hydrogen, and absorbed in 12 hours 6.6 c.c. or 5.116 vols. The steel again heated twelve hours at a higher temperature, absorbed 7.00 c. c. = 5 42 vols. Total, 10.536 times the volume of steel used.*

The evolution of carbonic oxide, in part, at least, appears to be due—1. To the reducing action of carbon on the silicious material of which porcelain is composed. Iron wrapped in platinum, and therefore not in contact with silica, gave considerably less carbonic oxide. 2. Iron and steel may contain oxide of iron which is reduced to the metallic state by carbon with a consequent evolution of gas. The evolution of carbonic oxide may be the result of these reactions, yet Graham affirms that iron contains the gas in solution. It is difficult to conceive how any alloy or combination of iron and carbonic oxide can exist: neither is it probable that either molten iron or steel can absorb or, say, dissolve, the gas without decomposing it. In casting ordinary steel ingots, air is carried down into the moulds entangled in the falling stream of molten metal, and nothing would appear more probable than that a portion would remain imprisoned in the steel, thus forming bubbles. The experiments of Müller and Richards show, however, but little carbonic oxide and only a small proportion of nitrogen, yet more than was found by the author. The quantity of nitrogen in the more recent and perfect experiments was so small, that it was considered doubtful by the author whether iron or steel contained any. Further

*In apparatus constructed to show directly the quantity of gas absorbed by the metal. The indirect method of first heating in a gaseous atmosphere, and then extracting the gas assumed to be absorbed by reheating *in vacuo*, is not reliable, inasmuch as iron and steel always evolve CO as previously stated. Wrought iron and steel were heated in CO with like result.

† Other samples Bessemer steel were found to contain (1) 0.5, (2) 1.6, (3) 2.00, (4) 1.00 of iron oxide.

* Overblown burnt steel gave 7.4 per cent. iron oxide.

experiments are needed to test the truth of Graham's statement. If it can be shown that carbonic oxide is insoluble in iron, it cannot be reckoned as a constituent of either iron or steel.* It must not, however, be forgotten that the presence of oxygen in steel is prejudicial. It is well known that steel contains oxygen, presumably as oxide of iron, and that overheated, burnt, or oxidized steel is a common product.

Hydrogen in Iron.—There can be no doubt that iron and steel are capable of absorbing many times their own volume of hydrogen, which is admitted to be a metal allied to magnesium. It may, therefore, be said to alloy with iron. Matthieson states that in nearly all cases alloys may be defined as solidified solutions of one metal in another. In certain alloys, such as gold and lead, tin or zinc, and some of the amalgams, the existence of chemical combination is indicated. Matthieson, moreover, is of opinion that carbon and iron may be said to form alloys behaving in an analogous manner to other alloys which cannot be looked upon as chemical combinations. No quantitative determinations of hydrogen or other gas have yet been made; all the results given are inconclusive on this point for the reasons previously stated. It is, moreover, very possible that no exhausted vessel heated from the exterior remains perfectly gas tight at the high temperature which appears necessary, although actual results with empty tubes so far disprove this. To remove all uncertainty arising from possible leakage, the author proposes heating the metal (enclosed in an exhausted glass globe) by means of the electric current derived from a powerful battery, or, better still, a dynamo machine. A bar of metal large enough for subsequent mechanical or chemical tests might thus be treated. With a properly constructed apparatus, there would be no errors from leakage due to the possible porosity of the heated tube, thus affording a fair chance of quantitatively determining the hydrogen, &c., evolved. The matter thus volatilized may be examined with the spectroscope with possibly interesting results.

Mr. Lockyer has stated that iron heated *in vacuo* with the spark from a powerful induction coil evolves a vapor, the spectrum of which shows the sulphur and phosphorus lines. It occurred to the author that possibly iron heated in the vapor of metals other than hydrogen might absorb, occlude, or more correctly ally with the metal, and this impression proved to be true. Iron heated in either volatilized zinc, magnesium, cadmium, or bismuth, is capable of absorbing minute quantities of the elements named, which are again evolved on reheating the metal just as with hydrogen; and that these are alloys in the ordinary sense of the term may be inferred from the fact that copper is converted into brass by merely heating it in zinc vapor. Brass, is, of course, only formed on the surface, the interior being copper; but it requires only prolonged action to render the conversion complete. Iron also absorbs in a similar manner both sulphur and phosphorus, but these are not evolved on reheating. With the latter true chemical combinations with iron appear to be formed, which are not decomposed at ordinary temperatures. If we admit this conclusion, it seems that of certain elements contained in iron and steel some may form alloys, as defined by Matthieson, while others may be in chemical combination. It may be inferred that the former class are unstable at ordinary temperatures of fusion, whilst the latter under all known conditions of temperature remain permanent. It need hardly be said that if we admit the above classification of alloys, a wide field for investigation remains to be explored, especially as regards Bessemer steel, and, to begin with, the exact quantitative determination of hydrogen in steel becomes of primary importance; carbonic oxide should also be determined, whether in combination or otherwise, as affording a measure of the quantity of oxygen. Admitting that alloys (with few exceptions) are merely solutions of one metal in another; that to secure an alloy of even composition throughout, the fused mass must be suddenly cooled, and that carbon with some of the metals

* "A new kind of porosity in metals may be imagined of a greater degree of minuteness than the porosity of charcoal and earthenware. This is an intermolecular porosity, due entirely to dilatation on heating; the porosity of iron or platinum is not sufficient to admit of the passage of gas at low temperatures. Under these conditions, carbonic oxide may possibly permeate iron or steel without forming a chemical combination or alloy."—*Deville.*

are simply dissolved in pure iron; it is probable that such a material as cast steel, the temperature at which it is cast and the rate of cooling must largely influence its physical properties. Quick cooling attended with agitation may (as with other alloys) tend to the formation of a homogeneous mass of even chemical composition; slow, undisturbed cooling would have the opposite effect, and these two steels might, on being tested, give results very different. In other words, steel should be as quickly as possible worked into the desired form.

Professor Akerman's statement that carbon may exist in steel in three different states, and Mr. J. W. Spencer's carbon determinations by the color test, showing discrepancies in the same sample of steel according to the mode of treatment, plainly indicate that carbon is simply soluble in iron; and as the amount existing in solution is determined by the method of treatment, it is probable that the insoluble portion has no effect whatever on the temper of the finished steel, but may nevertheless again be dissolved under suitable conditions. Chernoff states that steel, at a temperature varying with the nature of the steel, loses its crystalline structure and becomes amorphous. He maintains that by slow cooling large and regular crystals are formed, while by cooling rapidly, with constant disturbance down to the proper point, a steel of finely-grained structure is obtained, and subsequent cooling has no effect, the latter being of course the better material.

Graham speaks of matter as existing in two forms—1st, the colloid, or amorphous form; 2d, the crystalline form. This statement may be said to be applicable to all bodies, and although Graham speaks of it only in connection with substances fluid at ordinary temperatures, solvents, and gelatinous matter, yet may we not assume that water containing gases and solids in solution is analogous to fluid steel, which is also capable of dissolving gases and solid matter? The temperature may indeed constitute the sole differences between them, water simply existing as such because ice is fusible at the normal temperature of summer, whilst molten steel, at a far higher range of heat, is simply another fluid requiring a certain reduction of temperature ere it becomes solidified or frozen. He states that ice may exist in both the colloid and crystalline form. Colloid ice is formed in contact with water at 0 degrees, and it has the elasticity and tendency to stretch and rend, seen in all colloid or non-crystalline bodies. On the contrary, when it is frozen at a few degrees below zero, it has a well-marked crystalline structure. May we not, then, suppose that something like this occurs in manipulating cast steel; that its structure, more or less crystalline, may depend upon the initial temperature either above or below a zero point, as yet unknown, at which it is solidified? It would seem that steel should be so manipulated as to avoid a crystalline structure, and to approximate as much as possible to the colloid or amorphous state, with all other elements, such as carbon, manganese, &c., uniformly diffused. The author submits the preceding speculations on the molecular and chemical constitution of steel, more with a view of affording matter for discussion than as a definite statement of what may occur under the conditions named.

REPORTS OF ENGINEERING SOCIETIES.

American Society of Civil Engineers.—The transactions for April contain:

Paper No. 218. The construction of the Second Avenue Line of the Metropolitan Elevated Railway. By Thomas Hall.

" No. 219. Exponent of the Principle of Moments.

Boston Society of Civil Engineers.—The Committee on Uniformity in Datum Planes presented the following report, the 20th, which was accepted and ordered to be printed:—

REPORT OF COMMITTEE ON UNIFORMITY IN DATUM PLANES.

To the Boston Society of Civil Engineers:

The committee to whom was referred the subject of *uniformity in datum planes for levels* would respectfully make the following

REPORT.

It appears to have been the custom of cities and towns, and also of engineers engaged on public works, to adopt, without any regard to uniformity, some arbitrary datum plane or base to which all levels and heights are referred. Cities and towns located on the seaboard have usually adopted for this plane of reference, so far as the committee have been able to ascertain, either mean high or mean low water, there having been no uniformity of method, however, some adopting one and some the

other, according to the caprice of the engineer at the time the datum plane was established. In some cities two systems even have been adopted and are still used.

The base established by the engineers at the time of the construction of the Boston Water Works (and still used, we understand) was "tide marsh level," or mean high water; but the one subsequently adopted by the first City Engineer, Mr. Chesbrough, for general city purposes (and it is the base used at the present time) was, or rather was intended to be, mean low water. Also, in other cities, the committee understand that different planes of reference for levels have been and are still used by different departments or corporations. This double system of levels in the same locality is very objectionable, and is likely to cause confusion, and may sometimes lead to serious errors.

The committee take this opportunity to protest against any repetition of such a double system where, in the first instance, it can easily be avoided.

The committee do not hesitate to say that, theoretically, some uniform plane of reference for levels would be of great advantage as a means of comparison in different localities; and if such uniformity were to be generally adopted, it appears to them that the *mean level of the sea* would be the most feasible one that could be used for that purpose. Although the mean level of the sea would be the most convenient, if not the only one, that it would be practicable to adopt for a uniform plane of reference, still there are other reasons why mean low water, or extreme low water, or even a lower plane than either, would be found to be preferable in cities and towns located on the seacoast, as it is always desirable to have the base or datum line low enough to avoid the use of minus figures.

In conclusion, the committee would say that after taking the whole subject into consideration, they believe there is no better way of reaching the end, acknowledged by all to be much desired, of uniformity in datum planes for levels, than by the adoption of the *mean level of the sea* for that plane. It will be accompanied by the inconvenience of minus heights, but they believe the mean level of the sea to be the only plane susceptible of being absolutely fixed, and that the *uniformity* and *fixedness* will, on the whole, overbalance the inconvenience.

THOMAS DOANE,
THOS. W. DAVIS, } *Committee.*
JOSEPH H. CURTIS,

Boston, April 20, 1881.

The President invited Mr Mitchell, whom he observed to be present, to express his views, and he responded as follows:—

MR. HENRY MITCHELL—He fully concurred in the opinion of the committee that the mean level of the sea is the proper datum plane. It is subject to less variation than any other water reference; it is independent of the range of the tide, and essentially so of all the movements of the sun and moon, except *declination.* In our North Atlantic, it is only the declination of the moon that affects the mean level of the sea in any considerable degree, and this amounts to only three inches at Boston. It has been determined, from the long series of observations made by the Coast Survey at the Dry Dock, that with the increase of the moon's declination, whether north or south, the mean level rises. In the Gulf of Mexico, the reverse rule is found to apply, with a maximum change of over six inches.

The unequal pressures of the atmosphere upon different parts of the ocean give rise to changes of mean level; and although it could hardly be expected that the local barometer would be any criterion for this change, it has been pretty well determined that a fall of one inch in the mercurial barometer at Brest is attended by a rise of the mean level of the sea of some sixteen inches; at Liverpool, about ten; and at London, seventeen. On our own coast the change is very small

The mean level rises as we go up a tidal river, precisely as if this river were tideless; but it does not change as we go through arms of the sea or into bays and lagoons. Different tidal systems have the same mean level, as ascertained at the two extremities of the proposed Cape Cod Canal, and on either side of the isthmus separating the Bay of Fundy from the St. Lawrence, or that separating the Atlantic from the Pacific.

While a series of observations extending over a half-year is necessary to determine the elevation of mean high or mean low tide, observations every fifteen minutes for a single calm day at time of mean declination of the moon have been found to give mean level on our coast; and one may feel entire confidence in the average from such very frequent observations, continued from zero to maximum declination of the moon in the stormless month of July. As before said, the sun's declination may be safely neglected.

It would be a good custom to inscribe upon all public buildings some definite elevations above the datum, providing in this way numerous bench marks.

Mr. Mitchell said, in reply to inquiry from the President, that he knew of no public work in the country referred to the mean level of the sea, high or low tide being the usual reference, and that he regarded the action of the committee in this matter as a step forward.

PREVENTION OF SMOKE.—At a meeting of the Society of Engineers, held on Monday evening, June 13th, a paper was read by Mr. A. C. Engert on the "Prevention of Smoke"

The author, in choosing the title of the "Prevention of Smoke," instead of the "Consumption of Smoke," gives it as his opinion that smoke, once produced by the atmosphere and while being carried by the air, cannot be consumed, as every particle is surrounded by a thin film of carbonic acid. When, however, smoke is condensed as soot, heat will liberate the carbon from the acid, and then the former will burn rapidly. If this theory is found to be correct, carbon cannot destroy the germs of disease floating in the air.

For the consumption of smoke, many ingenious and elaborate inventions are on record, but not yet adopted on account of expense and complexity of mechanisms. A simpler apparatus is, therefore, required.

To prevent smoke, the cold air must not be allowed to come in contact with the gases arising from green coals, and, for this purpose, the furnace is, so to speak, divided into two parts. The fire-door is removed from the boiler, and a box fixed on in front. On each side of this box rails are placed inside, on which a plate or shutter may rest, which can be pushed forward or backward as required. When pushed forward it passes within the boiler and drops over the fire bars some 18in., thereby cutting off the draft and preventing the condensation of the gases arising when fresh coals are put on, thus preventing smoke and the cooling of the boiler.

A still more simple apparatus can be made with the same results, if the opening or flue will admit a higher box. The shutters can be cast together in one piece at an angle of about 130°, to hang within the box on two pins or bolts, thus forming a swinging shutter. A rack is attached to the front of the shutter to regulate the movement.

The advantages of this apparatus are—the cooling of the boiler is entirely avoided, the gases are consumed so that smoke is prevented, and there is a saving of from 15 to 20 per cent of heat and coal.

In ordinary open fire grates the same object is attained—viz., the prevention of the cold air from coming into contact with the green coal, by removing the fire-lump, and substituting for it a cast-iron box, which stands out at the back and is open in front only, and which is filled with coal. Within this box is a movable iron plate, which can be forced forward, carrying with it the coals from which the gases have been extracted and consumed by the heat in front, or moved backwards when the box wants refilling. To regulate the draught so that the fire burns brightly in front, a plate is fixed under the grate, coming forward at the bottom. Another plate, resting on pins, is placed on the top of the box to prevent the flame entering the register.

By this simple apparatus a bright fire is maintained in front of the grate, half of the heat usually escaping into the chimney is saved, there is little or no smoke, and the smallest coal can be used, and is, indeed, preferable.

In kitcheners, stoves, and vertical boilers, a similar box to foregoing can be fixed, the movable plate being worked by a lever.

This invention is also of great importance to railway companies, as it can easily be applied to locomotives. A box is placed under the foot-plate, the whole width of the fire grate, and the coals put in from the top. By this means the gases are almost entirely drawn out of the coal and consumed, the result being very little, if any, smoke. To supply the grate, the coal is pushed forward by a movable plate and lever.

Whether applied to furnaces, ordinary open fire-grates, stoves, kitcheners, vertical boilers, or locomotives, the results of this invention, in each case, are a great saving of heat and fuel, and the reduction of smoke to a minimum.

ENGINEERING NOTES.

The Forth Bridge, and its Architect.—The fate of the Tay Bridge had the effect of directing public attention to the design, known to be in course of carrying out, for the erection of a still bolder viaduct over the estuary of the Forth; but the more curiosity was felt on this subject, the greater appears to have been the care exercised to prevent any particulars from becoming known. The usual and legitimate sources of information were carefully closed. At last it became known that the project was adjourned *sine die*, and then, of course, it was said that it was useless to inquire into its details.

The memoir of Sir Thomas Bouch, which has just appeared in the sixty-third volume of the Minutes of Proceedings of the Institution of Civil Engineers, has given some of the long-desired information as to the Forth Bridge, at the same time that it has described other works planned and executed by the energetic engineer whose career came to so melancholy a close. In 1864, plans were lodged for the Glasgow and North British Railway, in which it was proposed to cross the estuary of the Forth by a fixed bridge, three miles long. It was to extend from the southern bank to a point called the Stacks, about a mile above Charleston on the Fife shore. The piers were to consist of wrought-iron cyclinders, supported on a wide base on the silt bottom of the river. The bridge was to be 125 ft. above high-water level, and five of its spans, crossing the fair way of the river, were to be of 500 ft. span each.

An experimental pier was prepared and partly sunk in its place, and attracted much attention among professional men at the time. After considerable progress had been made, the project was abandoned, on the failure of Mr. Hodgson's policy as Chairman of the North British Railway. In 1873, however, Mr. Bouch projected a work of a much bolder kind. He removed the point of crossing to Queensferry, where the width was much reduced, but the depth much increased. Taking advantage of the position of the island of Inchgarvie, which is in the middle of the estuary, for the foundation of a central pier, the engineer proposed to cross the deep-water channels on either side by two spans of 1,600 ft. each, at an elevation of 150 ft. above high-water level. The piers were to be formed of iron columns, strongly braced, and the height of each from the foundation was 600 ft. Each span was to be supported by suspension chains, having a deflection of 375 ft., strong lattice girders forming the support of the roadway.

The directors of the several railway companies interested in obtaining a bridge over the Forth consulted a committee composed of Sir John Hawkshaw, Mr. W. H. Barlow, Mr. G. P. Bidder, and Mr. T. E. Harrison. At the suggestion of these engineers, an elaborate analysis

of the design was made by Mr. W. H. Barlow and Dr. W. Pole, assisted on some points by the Astronomer Royal. On the 30th of June, 1873, these gentlemen sent in their report, after examining which the four referees above-named reported:—"It affords us great satisfaction to be able to give our sanction to a work of so imposing a character, and to express our high approval of the skill, scientific research, and practical knowledge which have been brought to bear upon the elaboration of this interesting work."

On a testimony of this unequivocal nature a company was formed, in 1878; the contracts for the Forth Bridge were let, and on the 30th of September in that year the work was commenced. The fate of the Tay Bridge, on the 28th of December, 1879, alarmed the directors. The Board of Trade were awakened to the fact that their own responsibility was likely to become serious, and they made large demands of security; and the Forth Bridge Company resolved to abandon the undertaking, or to wait for a more convenient season for its prosecution.

It is a matter profoundly affecting the credit of the engineering profession in the United Kingdom, that the unhesitating approval of the Forth Bridge by a committee of four engineers should be either justified or retracted. It will be remembered that, with regard to the Tay Bridge, Sir Thomas Bouch had taken the precaution of seeking the advice of some of the same engineers. It not only was proved by the logic of fact, but was clearly to be read between the lines of the evidence, that proper allowances for the possible fury of the wind had not been made in this structure. But while the engineer of the bridge was, no doubt, directly responsible in this matter, it was too much left out of sight that he was not solely responsible. It may even be questioned, considering his large occupation, and the eminence of the men whose advice he sought, and followed, as to the provision to be made against wind, whether he should have been considered as principally responsible. There is an unpleasant aspect of the matter. The public would have been better satisfied if all those who planned, investigated, sanctioned and approved the designs of those two great estuary bridges had taken their fair share of responsibility for the disaster, and not left Sir Thomas Bouch to be crushed by the weight that they ought to have shared with him. Especially has the public a right to expect from the Institution of Civil Engineers some scientific information as to the provisions proper to be made to resist both the fury of the wind and the shocks of the ice in all railway bridges, as well as with regard to the circumstances under which structures proved by the event to be totally unsafe have been designed by engineers, sanctioned by Parliament, built by contractors, examined and passed by the Board of Trade, and overthrown by the ordinary action of a Scottish winter.

On the 29th ultimo, on the motion of Sir C. Forster, the House of Commons resolved to consider, in Committee, on May 2, the repayment of the money deposited as security for the completion of the Forth Bridge Railway. This marks the final abandonment of the scheme.—*The Builder.*

THE SUEZ CANAL.—The shareholders of the Suez Canal Company held their annual meeting on June 9th, at Paris, when the annual report was submitted and approved. A dividend of 21.89 fr. was declared, apart from the fixed interest of 25 fr. The report states that the gross receipts have amounted to 41,820,000 fr., and the gross expenditure to 28,841,000 fr., leaving a net profit of 12,979,000 fr. The most interesting part of M. de Lesseps' report relates to the traffic. During last year 2026 ships, with a tonnage of 4,344,519 tons, passed through the canal. From 1870 till then the figures had been as follows: In 1870, 486 ships and 495,911 tons; in 1871, 765 ships and 761,467 tons; in 1872, 1082 ships and 1,439,169 tons; in 1873, 1173 ships and 2,085,072 tons; in 1874, 1264 ships and 2,423,672 tons; in 1875, 1494 ships and 2,940,708 tons; in 1876, 1457 ships and 2,072,107 tons; in 1877, 1663 ships and 3,418,949 tons; in 1878, 1593 ships and 3,291,535 tons; in 1879, 1477 ships and 3,236,942 tons. The receipts during this period rose from 5,159,000 fr. in 1870 to 28,886,000 fr. in 1875 and 39,840,000 fr. in 1880. Last year 221 ships, with a total tonnage of 353,985 tons, passed through the canal for the first time. Compared with the previous year, this is an increase of 66 ships and 118,371 tons. The Ducal Line, Bird Line, Union Line, Rotterdam Lloyd, and Rubattino Company have each added one vessel to their fleet; the China and Japan Line, the Russian Line, and the Austro-Hungarian Lloyd each two vessels; the Anchor Line, Ocean Steamship Company, and the Peninsular and Oriental Company, each three vessels; the Orient Line and the Ligne Française, connecting Marseilles with the eastern coast of Africa, each four vessels; and the British India Steam Navigation Company, five vessels. A new postal line connecting England and Spain with the Philippine Islands has been started with five ships. A great trade movement has sprung up between Russia and the colonies of the Amoor and island of Saghalien. There are now some twenty vessels carrying on this new traffic independently of the "national fleet," which has also augmented the number of its ships. Two hundred and thirty eight steamers last year carried coal from England to different parts of the far East; fifty-seven carried rails and railway material to Kurrachee, and two vessels from New York laden with petroleum passed through the canal. There were also thirty-five vessels from Australia, two of which were entirely laden with fresh meat preserved in ice, twenty-seven with Chinese and Japanese products bound for New York, and twenty-six vessels which passed through in ballast to receive cargoes awaiting them at Indian ports. The report anticipates from the experience of the present year that it will show a still larger traffic than last year, though last year's return already showed, as above seen, an increase of nearly 40 per cent. on those of 1879. Since January last the British India Company have created a new regular service between England

and Queensland, and all the great regular lines have sent vessels to the traffic. As regards the Ismailia Canal, it has not yielded all the results that might have been expected, owing to the impediments which M. de Lesseps thinks the Egyptian Government, in its own interest, and in performance of its engagements, will soon remove, and in conclusion, as regards the irrigation canal from Ismailia to Port Said. M. de Lesseps has asked the Khedive to authorize him to form an Egyptian Limited Company to carry it out. Meanwhile, he has formed an association of founders to subscribe, without interest, 200,000 fr. necessary for making the studies and preparing the work. The founders have a right to 10 per cent. of the net profits and the reimbursement of their advances when the company is founded. The subscription to this association was immediately covered on the Isthmus, at Cairo, and at Alexandria.

The Nerbudda Railway Bridge.—A railway bridge of considerable dimensions was opened for traffic in Western India on the 16th ult. This was the new bridge designed by Sir John Hawkshaw to span the Nerbudda River at Broach, where it is about a mile wide. The bridge by which the Bombay, Baroda and Central India Railway has hitherto carried over its traffic was built about twenty years ago, and has shown itself liable from time to time to be damaged by the river floods during the rainy season. Five years ago, 25 out of the 69 spans which constitute it were carried away by a flood, whereupon the directors of the line determined on building the one which has just been completed, and which has taken three years and a half to construct. The Nerbudda is one of the most sacred of the sacred streams of the Hindoos, and it is a saying among them that while it requires three days' bathing in the Saraswati, seven days' in the Jumna, and one day's in the Ganges, to wash away sin, the mere sight of the Nerbudda suffices to purify. The natives do not regard the building of piers for the support of bridges in these streams as in any way defiling them, but rather look upon the bridges themselves as possessing something of a reflected sanctity in consequence. The new bridge over the Nerbudda is 4687 feet long, and the moving dimensions 14 feet wide and 15 feet 11 inches high. The whole cost of the structure (one third of a million sterling), with the exception of some £40,000, has been entirely met out of the surplus earned by the Bombay, Baroda and Central Railway over and above the amount required to meet the guaranteed interest.

The New Tay Bridge.—Examination of the foundations of the old bridge convinced Mr. Barlow that it was requisite to make more allowance than had been before done for the scour of the river, and that the safest and best plan would be to put in piers for a double-way bridge entirely independent of the old piers. The erection of the bridge on the slightly altered site will require the construction of two or three short pieces of railway, and from the shore to their junction solid stone piers will be employed. The total length of the new bridge is a little over 10,000 feet, or about two miles. It is similar to the old bridge with regard to the number of large openings. Each pier is opposite a pier of the old bridge. The calculations are made for double the wind pressure that will ever be brought to bear on holding-down bolts. In reply to a question very pertinently put by Viscount Folkestone, Mr. Barlow said that the wind pressure was calculated at 20lbs. per square foot, and that, in point of fact, the design allowed for 56 lbs. pressure of wind and train. This is close upon the allowance made by the American engineers, and is, in our opinion, ample, if it be regarded as a probable strain that is not unlikely to come upon the bridge—the breaking strength being at least double. It would not, in our opinion, be safe if the breaking tension is put at less than 120 lbs. per square foot of surface on which the wind can lay hold, so as to exert a leverage against the resistance; and no doubt this is what is meant by the evidence. The piers are to be solidly connected with the girders. The parapet will be of wrought iron, as a precaution in case of any vehicle leaving the rails. There are also strong balks of timber placed as fenders outside the rails. It is intended to use some portion of the old girders, after proper testing, in the new structure. —*Builder*.

Cesspool Emptying by Steam.—An attempt is being made to supersede the clumsy system of cesspool clearing which has been carried on in England hitherto. Our neighbors in France have long since effected this work in a more cleanly manner, and a company is being formed in England for working a French patent. The managing director, Mr. Thos. Lawrie, invited a number of gentlemen last Tuesday to Priory Park, Kew, in order to inspect the machines and witness their working. The plant consists of a van for carrying the 4-in. pipes, which are of various lengths, some made of galvanized iron, others of thick rubber for turning corners; a number of receivers, made of light steel plates, barrel shaped, and of a capacity of about 3½ cubic yards. They are mounted on framework on wheels, being easily moved by a pair of horses; and a small portable steam engine, to which is attached a vacuum pump to exhaust the air from the receivers.

On the ground (which was kindly lent for the experiments by Mr. McShean) was a cesspool ready for exemplifying working. A pipe was pushed down to the bottom of the pool, and other pipes were very expeditiously joined to it until they reached the receiver, to which the end was affixed. The engine was set to work to exhaust the receiver, and the noxious air, not allowed to escape, was burned or purified by fire; directly this was done the sewage rushed up the pipes into the receiver at the rate of about one cubic yard per minute. A glass top was arranged on one of the pipes in order that visitors might see the rapid traveling of the soil. The pool operated upon was of the average English size—six cubic yards—and the whole work can be done and the workmen ready to leave the premises within half an hour.

The plan is the invention of M. Talard, who commenced working it in Paris and environs last October.

At luncheon afterwards, Mr. Robson, architect, spoke of the complete success of the experiments, and the simplicity of the machinery, laying especial stress on the perfectness of the lever-joint fastening.

Mr. Arthur Cates, surveyor to the Woods and Forests, also expressed his appreciation of the apparatus.

The number of cesspools still remaining, and likely to remain, in England is very large, and it is asserted that Birmingham alone is able to boast of 50,000.

RAILWAY NOTES.

Of the 514 axles which failed during the year 1880, 278 were engine axles, viz., 251 crank or driving, and 27 leading or trailing; 25 were tender axles, 1 was a carriage axle, 192 were wagon axles, and 18 were axles of salt vans. 90 wagons, including the salt vans, belonged to owners other than the railway companies. Of the 251 crank or driving axles, 190 were made of iron and 61 of steel. The average mileage of 182 iron axles was 171,832 miles, and of 60 steel axles 174,039 miles. Of the 446 rails which broke, 336 were double headed, 85 were single headed, 13 were of the bridge pattern, and 12 were of Vignole's section; of the double-headed rails, 196 had been turned; 216 rails were made of iron and 230 of steel.

A Transaustralian Railway.—The more enterprising of the inhabitants of Queensland are agitating strongly for the construction of a line of railway which shall connect Brisbane with the Gulf of Carpentaria, and, by establishing a port on the north of Australia, shall divert a considerable part of the shipping traffic, and open out the natural resources of the colony. The railway would extend from Brisbane near the 28th, to Point Parker on the 17th parallel, and would therefore run in a northwesterly direction. A short portion of this railway, that from Brisbane to Roma, has been already made, and the problem remains for a poor colony to construct nearly 1000 miles of railroad, with various branches to connect with other railway systems on the continent. If Queensland is poor in money she is rich in land; and the railway, it is urged, would pass through the midst of an almost unequaled grazing country. The area is about double that of New South Wales, or 428,500,000 acres, which, estimated at 6s. 8d. per acre, is worth £142,800,000. The cost of the railway is estimated at £4,000,000, or about 3 per cent. of the total wealth; and it is proposed to make a belt 23½ miles wide on each side of the line at the price above mentioned. No doubt the project is an excellent one, and if the railway were constructed it would be not only of inestimable advantage to Queensland but to the rest of the world, by placing at the disposal of emigrants new homes, and by increasing to a large extent the production of the world. There remains, however, the great difficulty, that of finding purchasers for the tracts that would be offered, especially as the great tide of emigration sets towards the United States, which offer more substantial advantages in many respects than the new and far removed regions of northern Australia. The route suggested appears to offer many advantages over the projected railway to Port Darwin; and the Gulf of Carpentaria is stated to leave little to be desired as a harbor for large shipping.

Safety Appliances on Railways.—Steady, though very slow, progress is being made towards the complete equipment of our railway system with safety appliances. A return recently issued shows that the number and proportion of cases in which signal and point levers had been interlocked in 1879 and 1880 respectively were:

	1880.		1880.		Percentage interlocked.		Percentage increase in 1880 over 1879.
	Interlocked.	Not interlocked.	Interlocked.	Not interlocked.	1879	1880	
England and Wales	24352	5330	21491	4717	80.	82.	2.
Scotland	2887	1846	3087	1735	61.	64.	3.
Ireland	566	1135	686	1119	32.	38.	6.
Total United Kingdom	23905	8311	25264	7571	47.	77.	3.

Then as to the block system, the number of lines open for traffic, and the distance worked on the absolute block system in each of the two years were:

	1879.		1880.		Percentage of double line worked on absolute block system.		Percentage increase in 1880 over 1879.
	Length of double line open.	Distance worked on absolute block system.	Length of double line open.	Distance worked on absolute block system.	1879	1880	
England and Wales	7869	6803	7980	7128	86.	89.	3.
Scotland	1074	676	1086	773	63.	71.	8.
Ireland	566	94	567	94	17.	17.	nil
Total United Kingdom	9509	7573	9633	7995	80.	83.	3.

In England, it will be observed, both as regards the interlocking of points and signals and the adoption of the block system, the work is well advanced. In Scotland, however, much lee way has to be made up, and in Ireland the work may be said to have been little more than ommenced.

ORDNANCE AND NAVAL.

THE "POLYPHEMUS."—The completion of the Polyphemus gives a novel and apparently formidable addition to the British Navy, but one that must be regarded as largely experimental until it is submitted to the test of actual warfare. The appearance of the hull suggests that of the Winans cigar ship, but this effect is concealed by the false works and turrets. The vessel is 240 ft. long, and 40 ft. in extreme breadth; the draught of water being 19 ft. 6 in. forward, and 20 ft. 6 in. aft; the displacement is 2640 tons. She is built throughout of steel, and is framed with transverse brackets and continuous longitudinals, and with a double bottom the whole length of the ship. The lower part is subdivided into a large number of cellular spaces, while the whole is divided by a longitudinal bulkhead, and numerous transverse bulkheads, and the engine and boilers are contained in six water-tight compartments. Over the framing of the ship is placed a double plating of Landore-Siemens steel, each plate being ½ in. thick, and upon these is a thickness of Whitworth's fluid compressed steel in plates 10 ft. long, 2 ft. 6 in. deep, and 1 in. thick. The armor plates which cover the whole of the curved deck and sides below the water line are peculiarly arranged. They are also of Whitworth compressed steel, and are made in plates or scales 10 in. square and 1 in. thick. These scales overlap each other in such a way that the securing coned steel plugs, which are placed one in each corner, hold three adjacent plates, there being also one central plug. Forming a part of the rigid structure of the vessel are six steel-clad revolving turrets, three on each side, which will be armed with the heaviest class of Nordenfelt guns. At each end of the ship also there is an armored conning and steering tower, entered from the interior of the vessel. There are also two armor-plated ventilating shafts and a smoke stack. The superstructure reared upon the hull gives to the Polyphemus something of a ship-shape appearance. It consists of a forecastle rising 9 ft. out of the water, a main deck, and a flying deck carrying boats and two large life rafts; this superstructure is of course quite independent of the ship's framing, and may be all shot away without affecting her safety. A special feature in the Polyphemus is the absence of keel, a recess or groove 3 ft. 6 in. deep, 2 ft. 6 in. wide at the bottom, and 2 ft. at the top, being formed along the whole length in the position usually occupied by the keel. This groove is divided into sections by transverse partitions placed across it, each section being large enough to receive a length of cast iron 10 ft. long and weighing about 50 tons. At one end each of these blocks is hooked on to the partition in the groove, and at the other end it is held by a cam attachment operated from the interior of the ship, and which can be instantaneously released, and the block detached. The object of this peculiar arrangement is to enable the vessel to float with a lighter draught should she be damaged in action, or should any other necessity arise for such a measure, a difference of 12 in. or 14 in. being possible if all the 300 tons of ballast thus carried is cast loose. Whether this device will prove satisfactory remains to be tested.

The engines of the Polyphemus were constructed by Messrs. Humphrys, Tennant & Co.; they are horizontal single piston-rod compounds with high-pressure cylinders 38 in. in diameter and low-pressure cylinders 64 in. in diameter, the stroke being 39 in. They are supplied from ten boilers of the locomotive type, with a working pressure of 120 lbs. per square inch. The engines have indicated 5500 horse power, and the estimated speed to be got with them is 17 knots. She will be propelled by three-bladed twin screws 14 ft. in diameter, and from 15 ft. to 17 ft. pitch, and for special manœuvring two bow rudders are provided which can be housed within recesses when not required. A part of the armament of this curious vessel has been already referred to. The Nordenfelt guns mounted in the six turrets will be able to enclose her within an almost solid veil of lead, and no small boat could live within the circle of their fire. But besides this they should be useful within limits for offensive operations also, though of course they would be useless at long ranges or against armor. But the real offensive strength of the Polyphemus lies in the fact that she may be regarded as a gigantic torpedo to be hurled bodily at the top of her speed against an enemy, which if fairly struck would have no alternative but to go down, and as she can be very easily handled, and possesses a high speed she should prove a formidable antagonist in this mode of fighting. The striking weapon consists of a ram projecting about 13 ft. beyond the hull, and placed so far below the water level as to render it most effective against the unprotected hull of an adversary. This ram, which is strongly framed on to the hull and armor plated is terminated by a solid steel spur forming a cap which, when desired, can be turned up, and a circular opening within the ram exposed. From this opening the Whitehead torpedo can be discharged, so that this part of the ship forms not only a formidable weapon for assault but also the appliance whence the smaller implements of destruction will issue. There are, moreover, four other torpedo ports, two on each side near the bows, and spar torpedoes will be carried on deck.

The Polyphemus, which was built at Chatham, and has cost about £150,000, was launched on Wednesday last, with engines and boilers fitted, but without armament, stores, or ballast. She will now be moved into one of the docks of the yard, and her final fittings completed without delay, so that she will probably be ready for trial within two months. It may be well here to recall some remarks made in the House of Commons by the late Mr. Ward Hunt on the 12th of March, 1877, when he was describing the general features of the Polyphemus. He said on that occasion "that this vessel must, of course, to a certain extent, be regarded as an experiment, and even supposing it to be a success, I could not propose it to the House as being likely to supersede all other

kinds of fighting ships, but only as a useful adjunct to a fleet in case of war. Probably it would not be desirable that she should be kept at sea for a long period at a time, but I venture to think she will prove a very formidable weapon, and if she should be a success, she may be regarded as a sort of rival to those monster ships with tremendous armor we hear spoken of as likely to be built in some foreign ports."

A New Torpedo.—Another invention has just been added to the already long list of marine infernal machines. A Roumanian engineer has invented a new description of torpedo or submarine boat, whose peculiarity is that it is capable of manœuvring under water for twelve hours at a stretch. It is able to act at depths of from a hundred feet in rivers to seven or eight hundred feet in the sea. It is able, through the agency of screws, to rise or sink noiselessly, and either suddenly or gradually by successive stages, and can move or manœuvre in any direction. The illumination of the vessel is internal, and enables the officers upon her to see for a distance of a hundred and thirty feet under the water. Upon the surface of the water the vessel is managed and manœuvred as any ordinary ironclad boat. If everything that is affirmed concerning this new torpedo boat is true, it will be a decided improvement upon that most eccentric vessel ever constructed in this country, Polyphemus, launched last Wednesday.—*Iron.*

BOOK NOTICES.

Publications Received.

Proceedings of Institution of Civil Engineers. Deep Winning of Coal in South Wales. By T. Forster Brown, M.I.C.E., and G. F. Adams, M.I.C.E.

Bulletin of the Museum of Comparative Zoology at Harvard College. No. 3. On an Occurrence of Gold in Maine. No 4. A Microscopical Study of the Iron Ore of Iron Mine Hill, of Cumberland, R. I. By M. E. Wadsworth.

The Principles of Myodynamics. By Jarvis S. Wight, M. D. New York: Bermingham & Co.

Second Geological Report of Pennsylvania. Report on the Causes, Kinds and Amount of Waste in Mining Anthracite Coal. By Franklin Platt. Harrisburg: Published by Board of Commissioners.

The greater portion of this work is of the thoroughly practical order, which the title clearly indicates; a chapter in the distribution of the anthracite, however, is of more general interest. The process of mining, also, is so lucidly explained, that it deserves publication as a separate essay.

The illustrations are exceedingly numerous and very plain.

Note-Book of an Amateur Geologist. By John Edward Lee, F.G.S., F.S.A. London: Longmans.

For many years Mr. Lee has been in the habit of keeping a note book, in which anything bearing either on geology or archæology might be entered, and as he has evidently been an industrious rambler, the collection of notes and sketches grew to such dimensions that his friends urged him to publish them. The result is that we have a volume which will certainly be found of interest by other amateur geologists, and which will be welcome in the library of the professor of the science. Altogether there are 209 plates of sketches which, intended as aids to the memory, represent what was actually seen at the time. A friend of the late Professor Phillips, to whom he owes much of the information he possesses, Mr. Lee has evidently imbibed much of the spirit of that distinguished geologist, and his "notes" and sketches will be very welcome to many other workers in the same field. The expense attending the production of such a book as this is necessarily great; but Mr. Lee promises that if, contrary to his expectation, the present volume should be so well received that the loss on its publication is not very large, he will probably issue his archæological notes. The sketches cover a wide field, for they show that Mr. Lee has visited many parts of England and Wales, Scotland, Italy, France, Switzerland, Sweden, and other countries. The notes are short and to the purpose, the author's object being merely to describe the diagrams and sketches, not to write a treatise on geology. We think that students of the science will thank him for the publication of his notes, for those who cannot follow the same track will be able to form an opinion of the natural objects depicted, and those who have leisure to make tours will learn from them where to go, and will feel a pleasure in comparing notes.—*Eng. Mechanic.*

A Practical Treatise on Mechanical Engineering. By Francis Campin, C.E London: Crosby Lockwood & Co.

This work is substantially an abridgment of the author's larger treatise; but it has been entirely rewritten, the improvements in mechanical manipulation having rendered obselete many of the processes described in the earlier treatise. "A quantity of descriptive matter has been eliminated, and replaced by accounts of vacuum brakes and other modern appliances," and we must suppose that the author had good reason for eliminating the matter left out; but why he should have given us a chapter on railway and tramway appliances mainly devoted to a description of the Eames vacuum brake and Hardie's tram rail, passes comprehension. Mr. Campin seems to be unaware of the existence of other vacuum brakes and of the Westinghouse automatic pressure brake, and, accordingly, we find the following sentence in this remarkable chapter:—"There is great difficulty in determining the relative efficiencies of brakes, because there have never yet been made any trials which afford information on the subject of any practical value." The author is apparently aware that trials have

been made: but the tables and reports are so "utterly worthless," that it is almost a waste of space to point it out; still, for the benefit of his young readers, Mr. Campin ventures on a little explanation. In the trials referred to, he says "the retarding effects of the train-friction *has* not been taken into consideration,"—a statement which is incorrect in phraseology, as well as in the meaning it is intended to convey.—*Eng. Mechanic.*

MISCELLANEOUS.

Coating of Metals.—To protect metals against the oxidizing influence of a damp atmosphere has long been an object of research of a great practical importance. It is well known that a bright sheet of zinc, such as is used in covering roofs, very rapidly gets covered by a thin layer of oxide, and that this thin film becomes so thoroughly united to the metal below that it forms a firm coating and protects the metal against further oxidation. A precisely similar object has been followed by several inventors with regard to iron when they endeavored to provide it with an adhering coating of black magnetic oxide of iron. This was done successfully in 1860 by Thirault, who employed a solution of chloride of iron, which was well rubbed upon the metal and gave it a black luster, when the artificial rust was converted in the black oxide after having been dipped in boiling water. In 1862 a similar result was obtained by Sauerwein, who used besides chloride of iron, chloride of antimony and gallic acid, while another method was to cover the surface of iron with linseed oil and to expose it then to a dull red heat. By the process of Barff, in 1877, such a coating is obtained by subjecting iron at a dull red heat for six to seven hours to dry steam, when a black fast-adhering coating will be formed. More recently another method, of Mr. Bower, came in use, and it is now carried out on a large scale by a French company, the Société Francaise d'Inoxidation, which has its works at Val d'Osne. The coating of the iron articles is produced by first cleansing their surfaces and then by heating them in a furnace to a light red heat, when successively currents of carbonic oxide and carbonic acid are passed through it. In this way a bluish black oxide of iron is formed upon either cast iron, wrought iron or steel. This oxidized surface, on being polished with oil, takes a beautiful luster, and it is further ornamented by scraping some parts of it free from the coating, which are then either covered with a thin layer of bronze, gold or platinum, by galvanic action, after the invention of M. Dodé. Many articles made by the Société d'Inoxidation, such as statues, vases, fountains, bas-relievos, fire-grates, stoves, balconies, candelabra, railings of staircases, and others, are really of a very beautiful appearance

At a meeting of the Paris Academy of Sciences, a paper was read "On the Principle of Conservation of Electricity," by M. Lippmann. The principle is expressed by a condition of integrability. In the memoir, the author's method of analysis is applied to various phenomena—dilatation of glass of a Leyden jar during charge, electrization by compression of hemihedral crystals, and pyro-electricity of crystals The existence and law of certain new phenomena, not yet verified, are deduced.

M. Gilet de Grandmont repeated to the French Academy of Sciences on Monday last a curious optical experiment. The apparatus consists of a black disc with five apertures; behind this is placed a white or colored disc If the upper part of the disc near the center be regarded fixedly for some seconds, and the colored disc be then rapidly replaced by the white disc, the eye does not perceive the white through the apertures, but the complementary color of the colored disc which has been removed.

The following paragraph from the preface to "Elementary Lessons in Electricity and Magnetism," by Sylvanus P. Thompson, shortly to be published by Messrs. Macmillan & Co., has been communicated to *Nature* because of the similarity of the views therein to those in a paper by M. Lippmann, published in the *Comptes Rendus* of the 2nd ult. Mr. Thompson's MS. was in the hands of his publisher in March last, so that no doubts as to originality need arise: "The theory of electricity adopted throughout is that electricity, whatever its nature, is one, not two; that electricity, whatever it may prove be, is not matter, and is not energy; that it resembles both matter and energy in one respect, however, in that it can neither be created nor destroyed. The doctrine of the Conservation of Matter, established a century ago by Lavoisier, teaches us that we can neither destroy nor create matter, though we can alter its distribution and its forms and combinations in innumerable ways. The doctrine of the Conservation of Energy, which has been built up by Helmholtz, Thomson, Joule, and Mayer, during the last half century, teaches us that we can neither create nor destroy energy, though we may change it from one form to another, causing it to appear as the energy of moving bodies, as the energy of heat, or as the static energy of a body which has been lifted against gravity, or some other attracting force, into a position whence it can run down, and where it has the potentiality of doing work. So also the doctrine of the Conservation of Electricity, which is now growing into shape, but here first enunciated under this name, teaches us that we can neither create nor destroy electricity, though we may alter its distribution—may make more to appear at one place and less at another—may change it from a condition of rest to that of motion, or may cause it to spin round in whirlpools or vortices which themselves can attract or repel other vortices. According to this view, all our electrical machines and batteries are merely instruments for altering the distribution of electricity by moving some of it from one place to another, or for causing electricity, when heaped up in one place, to do work in returning to its former level distribution."

VAN NOSTRAND'S

ENGINEERING MAGAZINE.

NO. CLIII.—SEPTEMBER, 1881.—VOL. XXV.

THE KINEMATICS OF MACHINERY.

By PROF. ALEX. B. W. KENNEDY, C. E., of University College, London.*

Lecture II.

We shall in the present Lecture examine in some detail a few of the results which can be obtained by treating mechanisms upon the plan which Reuleaux has proposed, and which is illustrated by his models; that is to say, by the analytical treatment of which we have already seen the general nature.

We have seen how kinematic chains are built up from pairs of elements and links. The pairing and the linkage renders the relative motions in the chain absolutely determinate, and the determinate relative motion exists equally whether or not any link of the chain be fixed relatively to the earth or to any portion of space that we choose to treat as stationary.

We have now to consider in more detail the effect of fixing one link of the chain. In practice, of course, one link is always fixed, or in other words, its motion relatively to the earth, to a locomotive or whatever it may be, is made zero. A chain with one link fixed is simply what we know as a mechanism.

In examining pairs of elements we saw that we could fix either element of the pair with lower pairs, the relative motions remaining unaltered; with the higher pairs the inversion gives us a totally different motion. We have seen also that we can fix any one link of a kinematic chain just as we can fix either element of a pair. We therefore can get as many mechanisms from any chain as it has links. From any such chain as Fig. 3, for instance, which has four links, we can get four mechanisms. The fact that a kinematic chain gives us as many mechanisms as it has links appears, looked at from this point of view, a mere matter of course. It has, however, never been hitherto distinctly recognized, so far as I know, and it can hardly be realized too distinctly, the consequences which result from it being most important, as we shall see. All that I shall attempt to do in this lecture will be to look at some of the mechanisms obtained from the particular chain just mentioned, and various modifications of it.

We have already noticed that the chain has four links. We see further that it is a chain in which all the motions are conplane, each of its four pairs being simply a cylinder pair, and the four cylinder pairs having parallel axes. It is so proportioned that by causing one link to swing, another one can be made to revolve. In order that we may refer more easily to the links, a letter is attached to each in the engraving.

For convenience sake we may also use

* Abstract of lectures delivered at South Kensington.

a short symbol for this chain (the one used by Reuleaux) namely, (C''_4).* The C_4 within brackets stands for the four cylinder pairs, the symbol for parallel being added to indicate their relative positions. This is the symbol for the *chain*, no link being fixed. To distinguish the four mechanisms formed from

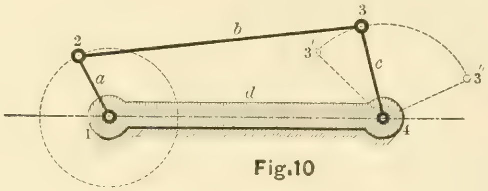


Fig.10

it, we shall put the letter which stands for the fixed link in the position of an index after the formula. Thus we can denote the particular mechanism shown in Fig. 10, in which the link d is fixed, by the formula $(C''_4)^d$. We have here then, the first of the four mechanisms we can get from this chain. You will recognize it easily enough as exactly similar to the beam and crank of a beam

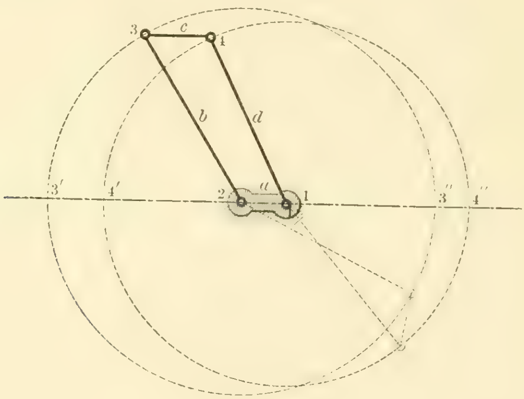


Fig.11

engine. The link c is half the beam, a the crank and b the connecting rod. The whole mechanism is an excellent illustration of what I said in my last lecture, that the *form* of the links is indifferent. If you think of the mechanism as forming part of a beam engine, for instance, you will see in the link d the abstract form of what is generally a most complex structure, a bed plate with its bearings, an entablature and plummer block, cast iron columns, and in some cases even brick and masonry. All these are represented by the fixed link d so far as their kinematic relations are concerned.

If now we fix the connecting rod b instead of fixing the link d as before, we have the mechanism $(C''_4)^b_{\parallel}$. It does not essentially differ from $(C''_4)^d$. The crank now revolves about the pin 2 which was formerly the crank pin, and the pin 1, which formerly represented the crank shaft, is now the crank pin, but there is nothing changed in the nature of the mechanism. By this inversion therefore we have got nothing new.

Let us now fix the link a, which was formerly the crank (Fig. 11). We have now the mechanism $(C''_4)^a$; it contains precisely the same elements as before, and the relative motions of the links are unaltered, but as a mechanism it is entirely different. It is now a combination frequently enough used in mills and elsewhere, known by the name of a "drag-link coupling." The links b and d have

* In words "C parallel 4."

become cranks, and one drives the other by means of the link c.

By fixing the remaining link of the chain, the link c, (which we have supposed to be longer than a), we have the entirely different mechanism $(C''_4)^c$, (Fig. 12). The two arms no longer revolve but only swing, and the link a turns right round once in every double swing of d and b. This mechanism is occasionally used in part of its stroke in parallel motions with some modifications, but is not so well known as the others.

The four inversions of this one chain, therefore, give us three different mechanisms. Looked at separately it is hard to see the relation in which these stand to each other; from the point of view which we have taken their mutual relationship has become at once evident.

in the direction of the axis of d or b. If no means be taken to prevent it, it is then possible to move the crank either in one direction or the other, and the two cranks may go on revolving in the same direction, or may revolve in opposite directions according to circumstances.

Such an indeterminateness is, of course, inadmissible in machinery, where we therefore adopt the well-known method of combining two mechanisms of the same kind, and placing them with their cranks at right angles, so that they do not cross the dead points at the same time. The motions are thus made determinate and the cranks revolve in similar directions. We might, however, wish them to revolve in *opposite* directions, as in the mechanism shown in Fig. 9. It

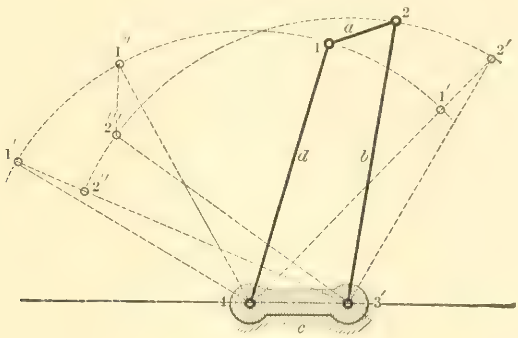


Fig.12

Without altering the pairing at all, we can greatly alter the chain by changing the relative length of its links. If we made all the links equal we should have a square, of which all four inversions would give similar mechanisms. If we make $b=d$ and $c=a$ we get a mechanism which is perfectly familiar in the couplings of locomotives and many other cases. All four mechanisms are again similar, each one consisting of a pair of cranks revolving with equal velocities and connected by a link which moves always parallel to itself.

These mechanisms are among those which have the peculiarity to which I alluded yesterday, that in one of their positions their motions are not determinate. This occurs at the "dead points" when a and c are both standing

may be worth our while to look for a moment at the means which may be used in this case to secure the determinateness of the motions in the mechanism. To distinguish between the two cases we may call the former "parallel cranks" and represent it by the formula $(C''_2 \| C''_2)$, and the latter "anti-parallel cranks," $(C''_2 \nparallel C''_2)$. This chain, with the link d fixed, is shown in Fig. 13.

In the case of the parallel cranks all points of the centroids of b and d are at infinity, for they are at the intersections of the parallel links a and c. We have already seen, however, that in the mechanism Fig. 9 the centroids are quite different, those of b and d being hyperbolæ. If, therefore, when the mechanism is brought into either dead point, where the cranks might change from the anti-

parallel to the parallel position, we can only make certain that the right centroids roll upon each other, we shall get the motion that we want. Fig. 13 shows an arrangement by which, just in that position of possible change, a tooth made on one link and a recess upon the other link gear together at a point corresponding to the point of contact of the centroids. The teeth G and H are virtually formed upon the centroid of b, and the recesses

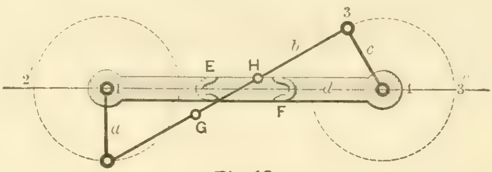


Fig.13

E and F upon that of d. At the points where these come into gear, the two centroids are compelled to roll upon one another, just as the pitch circles of two toothed wheels are compelled to roll on one another, and in this way the mechanism is carried over its only indeterminate point, and the cranks remain continuously anti-parallel and revolve in opposite directions.

This anti-parallel chain gives us two different mechanisms. Fig. 13 shows us

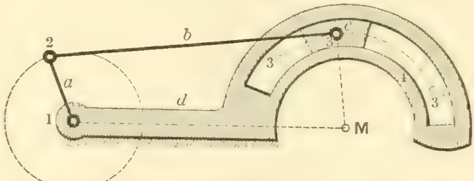


Fig.14

$(C''_2 \mathbf{Z}\, C''_2)^d$. In the other mechanism $(C''_2 \mathbf{Z}\, C''_2)^a$ the two cranks revolve in the *same* direction with very varying velocity ratios.

Returning again to the chain (C''_4), it will be seen at once that we may substitute for the pair of elements at 4 a slot and a sector concentric with it, as in Fig. 14. The motions remain entirely unaltered. By adopting this contruction, however, it becomes possible to construct the mechanism without covering with it the center of the pair 4, *i. e.*, the point of intersection of the links c and d. We can therefore lengthen these links without making the mechanism inconveniently large. The only constructive alteration is that the slot becomes flatter as the links are lengthened. If we lengthen them little by little until they become infinitely long, the curved slot becomes straight, and its center line will pass through the point 1. The mechanism modified in this fashion takes the extremely familiar form already shown in Fig. 8. It now contains three cylinder pairs with parallel axes; the fourth cylinder pair has become a straight slot with a block working in it, namely, a prism pair. The axis of the prism pair is normal to the axis of the three cylinder pairs, and we may therefore use the symbol $(C''_3 P^{\perp})$ for the chain in its new form. There are here again four links, and therefore four inversions, and we shall find that all four mechanisms are now different.

We have first the mechanism shown in Fig. 8, and familiar by its continual use in direct-acting engines $(C''_3 P^{\perp})^d$. Next, following the same order as before, we may fix the link b, the connecting rod of Fig. 8. The mechanism thus obtained, $(C'' P^{\perp})_{\underline{b}}$, is quite different from the former, but equally familiar (Fig. 15). To make it more recognizible, the prism pair 4 is *reversed* in the figure, that is the link c is made to carry the open prism and d the full one. The motion is obviously unaffected by the change. The mechanism can be easily seen to be that

of the oscillating engine. The link c corresponds to the cylinder, swinging on fixed trunnions at 3, and the link d to the piston rod and piston of the steam engine. We see, then, that the relation between the mechanisms which are familiar to us as the driving trains of the direct-acting and oscillating engines, is simply that they are different inversions of one and the same chain.

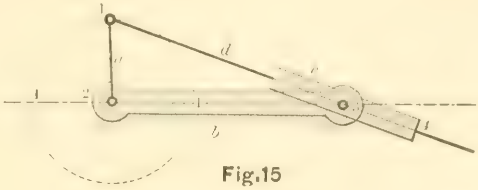


Fig.15

Let us now suppose the chain fixed upon the link which was the crank in the last two mechanisms (Fig. 16). This gives us a third mechanism which entirely differs from either of the two former ones. It is quite familiar as a "quick-return" motion in some machine tools, for which purpose also the mechanism last mentioned has sometimes been used.

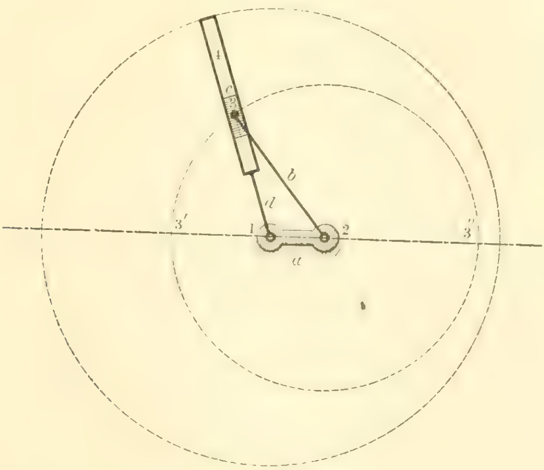


Fig.16

Fixing, lastly, the link c, we get the less familiar mechanism shown in Fig. 17 $(C''_3P\perp)^c$. The link b swings about 3, and the crank a rotates in space somewhat as in the mechanism $(C''_4)^c$, which we have already seen This train has some practical applications in machinery, but is not very often used.

Here, then, we have obtained from one and the same chain four entirely different mechanisms, all of them more or less familiar. The method we have adopted has again been successful in making the real relations of these apparently dissimilar things perfectly obvious.

We have seen in connection with Fig. 14 that we can to a certain extent alter the size and extent of a pair of elements without altering its nature or changing the motion of the chain to which it belongs. This alteration in the size of elements, or what may be called the "expansion" of elements, is a process continually carried out by engineers for practical constructive reasons; and often gives to identical mechanisms extremely different forms. It is impossible here to go into this in detail, a somewhat extreme case of it is shown, for the sake of

illustration, in Fig. 18. Here we have the mechanism shown already in Fig. 8, $(C''_3P\perp)^d$. The pin of the pair 2 is so enlarged as to include altogether the pair 3, the connecting-rod *b* being simply a circular disc, with an eccentric cylindric hole in it. The pin 1 again (the "crank shaft"), is made large enough to include

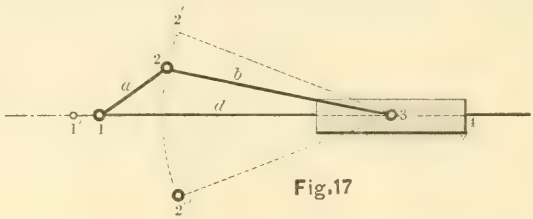


Fig. 17

the whole of 2. We have therefore 3 within 2, and 2 within 1. We have one very common illustration of the extent to which this expansion of pairs is carried practically in the link motion. The curved link and block are in their kinematic relations simply a very much expanded pair of cylindric elements reduced in extent by use of a process similar to

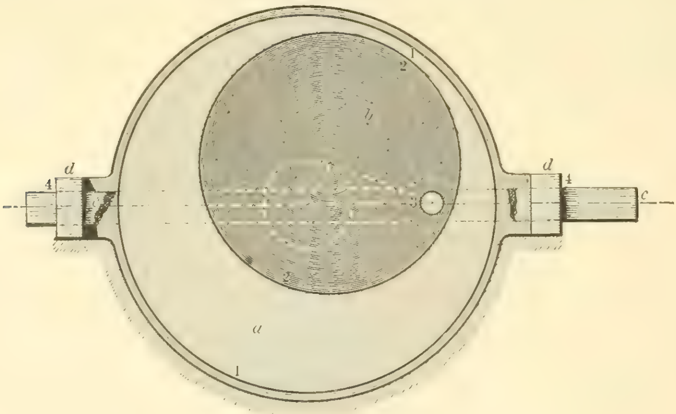


Fig. 18

that by which we got Fig. 14 from Fig. 10.

We have seen what results have been obtained by making two links of the chain (C''_4) infinitely long. The same process can be carried still further. In the familiar chain shown in Fig. 7, for instance, *three* links, *d*, *c* and *b*, are made infinite. We have therefore another prism pair in it, and its formula becomes $(C''_2P\perp_3)$. It gives us the two mechanisms already mentioned and a third one, all of which are practically applied.

We must pass over without mention many other modifications and alterations of the chain, and mention only one other form in which it occurs, a form which has some special interest. The condition of movability of a chain that contains four cylinder pairs is not that their axes should be parallel, but that they should *meet in one point*. The axes are parallel only in the special case where this point is at an infinite distance. Fig. 19 is an illustration of the more general, although less familiar, case when the point of intersection is at a finite distance. This chain, which may be indicated by the formula $(C_4^{\angle})$* has again its four inversions, and furnishes us with three different mechanisms as in the case of (C''_4). I cannot here go into these; I mention the chain partly because of its theoretic interest, and partly because—although it looks so unfamiliar,

* "C four oblique."

it is not unfrequently applied in machinery. If instead of subtending only a small angle, as in Fig. 19, three of the links were made to subtend an angle of 90°, we should have the common Hooke's or universal joint. In these "conic" chains, links which are quadrants take the place of the infinite links, so that a chain having three quadrants corresponds to the chain of Fig. 7, in which there are three infinite links. The formula of the universal joint is $(C_3^{\perp} C^{\angle})^a$; it corresponds exactly to $(C''_2 P_2^{\perp})^a$ and is analogous to $(C''_4)^a$ and $(C''_3 P^{\perp})^a$, Figs. 11 and 16 respectively. I have already mentioned in passing that the mechanism $(C''_2 P_2 \perp)^a$ is that of Oldham's coupling. We see then clearly the close relationship in which this coupling (for parallel shafts) stands to the Hooke's joint or coupling for inclined shafts. It is another illustration of the important results which follow naturally from Reuleaux's simple method of analysis, and which hardly seem attainable, certainly not with equal directness, by any other method.

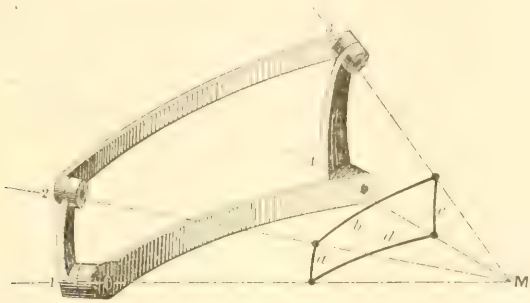


Fig.19

We may notice one other way in which the chain (C''_4), which we have seen in so many forms, may be modified. In some cases we may not wish to utilize the motion of all the four links, but (say) only three of them; in that case we may omit the fourth link, if we carry out a proper pairing between the two links thus left unconnected. If, for instance, we omit the link b we must make a proper pairing between a and d. This pairing will always be higher; the chain becomes a *reduced* chain. Such a chain, reduced by b, is shown in Fig. 20. The higher pairing is carried out by placing upon a a suitable element, here a circular pin at 2, and giving to c the form of the *envelope* of the motion of the pin relatively to it. This envelope is the curved slot shown in the figure. It was not necessary to take the new element at 2, but if it had been in any other place, as 2′, the form of the slot would have been more complex, as is shown by dotted lines. For such a chain we may use the formula $(C''_3 P \perp) - b$. The process of reduction can be carried on in this way until only two links are left,

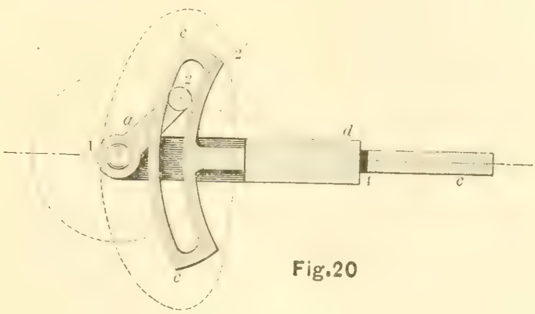


Fig.20

which then become really a pair of higher elements. It is constantly employed in machinery, mostly in the case of compound chains, or chains in which some links contain more than two elements.

The chain which we have been examining has been applied more often than any other to the leading trains of engines and pumps. We shall in conclusion look at a few of these machines, in order to notice the constructive disguises which often appear in them and render their kinematic identity almost unrecognizable.

Fig. 21 shows a rotary engine which

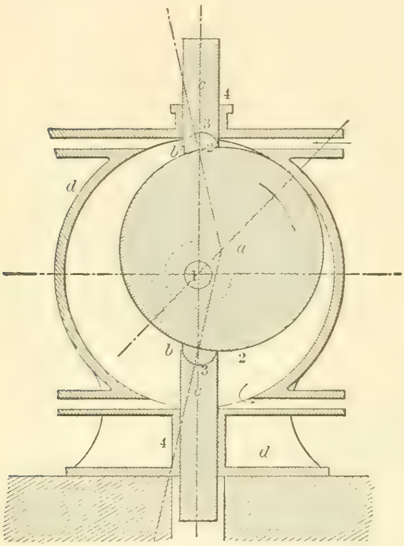


Fig.21

has been patented several times, and which is founded on the same mechanism, $(C''_3 P\perp)^d$, as the common direct-acting engine. The letters and figures placed upon it correspond to those on Fig. 8, so that the identity of the mechanisms may be the more easily traced. The extraordinary change of form undergone by the connecting rod *b* is worth special notice. It has become a bar having a cross section like a half moon. It still consists however, kinematically, of two cylinders or portions of them, one described about the axis of 2 (the center of the disc), the other about the axis of 3. The element 2 is expanded so as to include 1, the crank *a* becoming therefore a disc. The mechanism is so proportioned that the virtual length of the connecting rod—the distance, that is, between the centers of the elements 2 and 3, is equal to the radius of the disc *a*. With the mechanism in the form shown in Fig. 21 some separate means has to be provided for keeping *b* against *a* when the latter is moving upwards.

Fig. 22 is another rotary engine, which has been patented a dozen times since its first invention in 1805. It is based upon the mechanism of Fig. 16 $(C''_3 P\perp)^a$. The fixed link *a* is here made the steam cylinder, while *d* becomes a moving piston. The reference letters are the same as before. It will be noticed that the

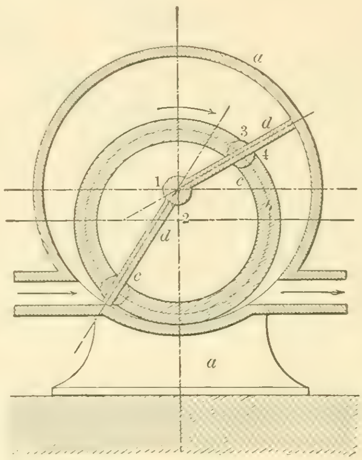


Fig.22

cylindric element of the link *c* is expanded to include its prismatic element; in all the cases formerly noticed the latter had been the larger.

In order to illustrate this part of his subject Reauleux examines (in the work I have already mentioned) some forty or fifty rotary engines and pumps all derived from the (C''_4) chain and such modifications of it as we have been looking at. Models of a number of these are now on the table before you. Many of them bear scarcely any external resemblance to the common steam engine, to which they are, notwithstanding their dissimilarity, so closely related. We are not now concerned as to which form is absolutely the best, but are only looking at them from a kinematic point of view. But it is worth noticing that in very

many cases not only constructive but mechanical advantages have been claimed for them. Their inventors have over and over again claimed some mechanical gain more or less mysterious, compared with the ordinary form of engine. Most of them, moreover, have been called "rotary" to distinguish them from reciprocating engines. Our method of analysis, although only kinematic, has shown us not only that there can be no mechanical advantage possessed by one over the other, but that the word "rotary" is essentially a misnomer, if it be supposed to

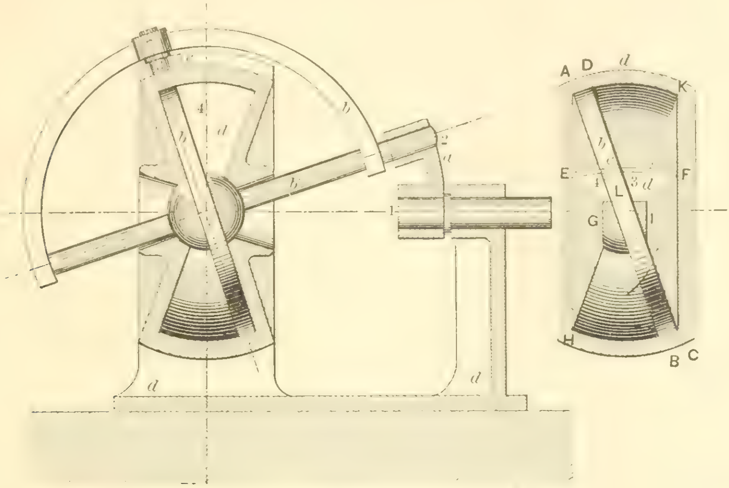


Fig.23

indicate that there is any more or different rotation in them than in ordinary engines.

We shall now only notice one more of these engines. It is one which has puzzled people a great deal, and with very good reason, for its motions are very strange, and its analysis apparently very complex.

The engine I refer to is shown (in one form) in Fig. 23. It is known as the "disc engine." It was brought a good deal into notice in 1851, and for a few years was used in the *Times* office without any ultimate success. Analysis shows that it is based upon the same chain as the Hooke's joint, the conic chain, namely, in which three out of four links subtend right angles, and of which the formula is $(C^{\perp}{}_{3}C^{\angle})^{a}$. The fixed link is, however, *d*, while in Hooke's joint *a* (the acute-angled link) is fixed. Patents have been taken out also for disc engines in which *a*, and others in which *b*, is the fixed link.

I may say, in conclusion, that while it may be impossible for many educational institutions in this country to possess themselves of models so perfect in execution, and therefore so expensive, as those which have been sent to the Loan Collection, it is yet quite practicable to construct many of them in a form which, while quite cheap, is yet well adopted for educational purposes. I have some made in this way of hard wood with brass pins, which are very serviceable for college purposes. It is just the simpler models, which are the most easily made, which are the most useful in instruction.

I venture to hope that the treatment of the theory of mechanism illustrated by the models now in the South Kensington Collection, and of which I have here endeavored to set forth some leading principles, may prove valuable in aiding the study and the comprehension of this branch of machine science both to the student and the engineer.

A RECENT English invention for a boring machine consists of a compound slide in the form of an inclined plane, the incline being in the direction of the length of the boring bar. By moving one part of the rest on the other the work is adjusted vertically.

MOLECULAR MAGNETISM.

By PROF. D. E. HUGHES, F.R.S.

From "English Mechanic and World of Science."

During the course of some late researches, which I had the honor to communicate to the Royal Society and experimentally illustrate on the reading of my second paper so many experimental facts occurred, all pointing to the conclusion that ordinary molar magnetism is entirely due to the symmetrical arrangement of its polarized molecules, and that these molecules can be rotated by torsion, so as to decrease its longitudinal magnetism, or increase it if the effect of the elastic torsion is to rotate the molecules in its required longitudinal symmetrical arrangement, and observing that molecular magnetism could induce an electric current upon its own molar constituents, or that an electric current by its passage through an iron wire would produce molecular magnetism, I have continued these researches in the hope of elucidating, as far as possible, the phenomenon of the transformation of electricity and magnetism by the changes produced in the molecular structure of its conducting wire.

For this purpose I have employed three separate methods of investigation, each requiring a slightly modified form of apparatus. The first relates to the influence of an elastic torsion upon a magnetic or conducting wire; the second the influence upon the molecular structure of an iron wire by electricity or magnetism; the third was the evident movement of the molecules themselves as given out in sonorous vibrations. The general details of the apparatus employed having been given, I will only briefly indicate any modification of the method employed.

1. INFLUENCE OF AN ELASTIC TORSION UPON A MAGNETIC OR AN ELECTRIC CONDUCTING WIRE.

In the paper just referred to I showed that induced currents of electricity would be induced in an iron wire placed on the axis of a coil through which intermittent currents were passing, and that these currents were produced only when the wire was under the influence of a torsion not passing its limit of elasticity. It became evident that if the intermittent magnetism induced by the coil produced under torsion intermittent currents of electricity, that an intermittent torsion under the influence of a constant current of electricity or a constant magnetic field would produce similar currents. This was found to be the case, and as some new phenomena presented themselves indicating clearly the molecular nature of the actions. I will describe a few of them directly relating to the subject of this paper. An iron wire of 20 centims. was placed in the center or axis of a coil of silk-covered copper wire, the exterior diameter of the coil being $5\frac{1}{2}$ centims., having an anterior vacant circular space of $3\frac{1}{2}$ centims. The iron wire is fastened to a support at one end, the other passing through a guide, to keep it parallel but free, so that any required torsion may be given to the wire by means of a connecting arm or index. A sensitive telephone is in direct communication with the coil, or a galvanometer may be used, as the current obtained by a slow elastic torsion are* slow and strong enough to be seen on a very ordinary galvanometer. I prefer, however, the telephone, because it has the inestimable advantage in these experiments of giving the exact time of the commencement or finish of an electric current. It has, however, the disadvantage of not indicating the force or direction of the current; but by means of the sonometer the true value and direction of any current is at once given. Again, the telephone is useless for currents of slow intermittence, but by joining to it the microphonic rheostat described in a previous paper a slowly intermittent or permanent current is broken up into rapid intermittent currents, and then we are able to perceive feeble constant currents. For this reason a microphonic rheostat is joined to the telephone and coil. The current from a battery of two bichromate cells is

* A paper read at the Royal Society, on May 19.

sent constantly through the wire if we wish to observe the influence of the torsion of the wire upon the electric current, or a constant field of magnetic energy is given to the wire by either a separate coil or a permanent magnet. The currents obtained in the coil are induced from the change in the molecular magnetism of the wire, but we may equally obtain these currents on the wire itself without any coil by joining the telephone and rheotome direct to the wire; in the latter case it is preferable to join the wire to the primary of a small induction coil, and the telephone and rheotome upon the secondary, as then the rheotome does not interrupt the constant electric current passing through the wire. As the results are identical, I prefer to place the telephone on the coil first named, as the tones are louder and entirely free from errors of experimentation.

If we place a copper wire in the axis of the coil we produce no effect by torsion, either when under the influence of a constant magnetic field or a current passing through it, nor do we perceive any effects if we place an iron wire (2 millims. in diameter), entirely free from magnetism and through which an electric current has never passed. I mention this negative experiment in order to prove that all the effects I shall mention are obtained only through the magnetism of the wire. If now I pass an electric current for an instant through this same wire, its molecules are instantly polarized, and I have never yet been able to restore the wire to its original condition, and the magnetization induced by the passage of a current is far more powerful and more persistent in soft iron than tempered steel. This may be due, however, to the fact that in tempered or softened steel we find traces only of a current during the rotation by torsion of its molecules some two to three degrees of sonometer, whilst iron gives constantly a current of 70 sonometric degrees.*

In order to obtain these currents, we must give a slight torsion of 5° or 10° to and fro between its zero point. We then have a current during the motion of the index to the right, and a contrary current in moving the index to the left. If we use a galvanometer, we must time these movements with the oscillations of the needle; but with the telephone it gives out continuous sounds for either movement, the interruptions being only those caused by the rheotome. The direction of the current has no influence on the result; either positive to the free arm or index or negative gives equal sounds, but at the moment of reversal of the current a peculiar loud click is heard, due to the rapid change or rotation of the polarization of its molecules, and this peculiarly loud momentary click is heard equally as well in steel as in iron, proving that it is equally polarized by the current, but that its molecular rigidity prevents rotation by torsion. We can imitate in some degree the rigidity of steel by giving the iron wire several permanent twists. The current due to elastic torsion is then reduced from 70° to 40°, due to the mechanical strain of the twists remaining a constant; and a weakening of the current is also remarked if with a fresh wire we pass in torsion its limit of elasticity.

If a new soft iron wire of 2 millims. (giving no traces of a current by torsion) has passed through it a momentary current of electricity, and then wire observed free from the current itself, it will be found to be almost as strongly polarized as when the current was constantly on, giving by torsion a constant of 50 sonometric degrees. If, instead of passing a current through this new wire, I magnetize it strongly by a permanent magnet or coil, the longitudinal magnetism gives also 70° of current for the first torsion, but weakens rapidly, so that in a few contrary torsions only traces of a current remain, and we find also its longitudinal magnetism almost entirely dissipated. Thus there is this remarkable difference, and it is that whilst it is almost impossible to free the wire from the influence produced by a current, the longitudinal magnetism yields at once to a few torsions. We may, however, transform the ring or transversal magnetism into longitudinal magnetism by strongly magnetizing the wire after a current has passed through it; this has had the effect of rotating the whole of the molecules, and they are all now symmetrical with longitudinal magnetism, then by a few torsions the wire is almost as free as a new wire; and I have found

* 0.8 of a Daniell battery.

this method more efficacious than heating the wire red hot, or any other method yet tried. If I desire a constant current from longitudinal magnetism, I place at one of the extremities of the wire a large permanent magnet, whose sustaining power is 5 kilometers, and this keeps the wire constantly charged, resembling in some respects the effects of a constant current. The molecular magnetism or the current obtained by torsion is not so powerful from this, my strongest magnet, as that produced by the simple passage of a current, being only 50 sonometric degrees in place of 70° for that due to the passage of a current. The mere twisting of a longitudinal magnet, without regard to the rotation of its molecule having no effect, is proved by giving torsion to a steel wire strongly magnetized, when only traces of a current will be seen, perhaps one or two degrees, and a constant source of magnetism or electricity then giving no measureable effect. Evidently we have equally twisted the magnetized steel as the soft iron. In the steel we have a powerful magnet, in the soft iron a very feeble one; still the molecular rotation in iron produces powerful currents to the almost absolute zero of tempered steel.

If we magnetize the wire whilst the current is passing, and keep the wire constantly charged with both magnetism and electricity, the currents are at once diminished from 70° to 30°. We have here two distinct magnetic polarizations at right angles to each other, and no matter what pole of the magnet or of the current the effect is greatly diminished; the rotation of the two polarities would now require a far greater arc than previously. The importance of this experiment cannot as yet be appreciated until we learn of the great molecular change which has really occurred, and which we observe here by simply diminished effects.

If we heat the wire with a spirit flame, we find the sounds increase rapidly from 70 to 90, being the maximum slightly below red heat. I have already remarked in my previous paper this increased molecular activity due to heat, and its effects will be more clearly demonstrated when we deal with the sounds produced by intermittent currents.

Another method, by means of which I have again received proofs of the rotation of the polarized molecule, is to pass an intermittent currency through a soft 0.5 millim. iron wire, listening to the results by the telephone joined direct and alone to the coil. If, then, the wire is entirely free from strain, we have silence, but a torsion of 20° producces some 50 sonometric degrees of electric force. If, now (the wire being at zero strain), I bring one pole of the permanent magnet I have already described near the side of the wire, the sounds increase from zero up to 50°, being at their maximum when this magnet is 5 centims. distant; but if we continue to approach the magnet the sounds gradually weaken to an almost zero. The explanation of this fact can be found when we know that the greatest inductive effect on the wire would be when a magnet is at an angle of 45° with the wire. And, also, considering each molecule as a separate independent magnet, we find that at a given distance for a given magnet the force of rotation is equal to that of 45°; by approaching the magnet we increase the rotation but diminish the angular polarity in relation to the wire, hence the decrease of force by the near approach of the magnet. And to prove that the function of the elastic torsion is simply to rotate the polarized molecules similarly to the magnet, we place the wire under an elastic torsion of 20°, and approach gradually the magnet as before. One pole now will be found to increase the sounds or its angular polarity, the other will decrease until at 5 centims. distance as before we have perfect silence; the torsion exists as before, but the molecules are no longer at the same angle. On removing the magnet we find that instead of the usual 50 of current we obtain barely 5 or 10; have we then destroyed the polarity of the molecules, or do they find a certain resistance to their free rotation to their usual place? To solve this question we have only to shake or give the wire a slight mechanical vibration, and then instantly the molecules rotate more freely, and we at once find our original current of 50°. I will forbear mentioning many other experimental proofs of my views by this method, as there are many to relate by different methods in the following chapters.

2. INFLUENCE UPON THE MOLECULAR STRUCTURE OF AN IRON OR STEEL WIRE BY ELECTRICITY OR MAGNETISM.

Being desirous to modify the apparatus already described, so that it would only give indications of a current if they were of a spiral nature, the wire was kept rigidly at its zero of strain or torsion, and the coil was made so that it could revolve on an axis pependicular to the wire; by this means, if the wire was free from strain, the center or axis of the coil would coincide with that of the wire. Thus with a straight copper wire, we should have a complete zero, but if this wire formed a right or left-handed helix, the coil would require moving through a given degree (on an arbitrary scale) corresponding to the diameter and closeness of the spirals in the helix; the degrees through which the coil moved, were calibrated in reference to known copper helices. 50° equaled a copper wire 1 millim. diameter, formed into a helix of 1 centim. diameter, whose spiral turns were separated 1 centim. apart.

In order to obtain a perfect zero and wide readings, with small angular movement of the coil, it is necessary that the return wire should be of copper, 2 millims. diameter, offering comparatively little resistance, and that it should be perfectly parallel with the steel or iron wire. In order that it may react upon the exterior of the coil, it is fastened to the board, so that it is near (1 centim.) the exterior of the coil, and parallel to the iron wire, at a distance of 4 centims. If we consider this return wire alone, we find, as in the sonometer, that if the wire is perpendicular to the exterior wires of the coil, we have a zero or silence, but moved through any degree, we have a current proportionable to that degree; by this means we have an independent constant acting on the coil, constantly aiding the coil in finding its true zero, and allowing of very wide readings, with a comparatively small angular movement of the coil.

The rheotome is joined to a battery of two bichromate cells, and by means of a reversing switch an intermittent current of either direction can be sent through the wire. The telephone is joined direct and alone to the coil, thus no currents react upon the coil when perpendicular to the iron, and its return wire, if not of a spiral nature.

Placing an iron wire 0.5 diameter, and passing a current through it, I found a change had taken place similar to those indicated in my second paper, but it was so difficult to keep the wire free from magnetism and slight molecular strains, that I preferred and used only in the following experiments tempered steel wire (knitting needles I found most useful). All the effects are greatly augmented by the use of iron wire, but its molecular elasticity is so great that we cannot preserve the same zero of reading for a few seconds together, whilst with steel, 0.5 millim. diameter, the effects remained a constant until we removed the cause.

I have not as yet been able to obtain a steel wire entirely free from magnetism, and as magnetism in steel has a remarkable power over the direction of the spiral currents, I will first consider those in which I found only traces. On passing the intermittent current through these, the sounds were excessively feeble for either polarity of current, but at each reversal a single loud click could be heard, showing the instant reversal of the molecular polarity. The degree of coil indicating the twist or spirality of the current was 5° on each side of its true zero. The wire was now carefully magnetized, giving 10° on each side for different currents. The positive entering at north pole indcating 10° right-handed spiral, negative entering the same pole, a left-handed spiral, we here see in another form, a fact well known and demonstrated by De la Rive by a different method, that an electric current travels in spirals around a longitudinal magnet, and that the direction of this spiral is entirely due to which pole of an electric current enters the north or south pole. I propose soon, however, to show that under certain conditions these effects are entirely reversed.

If through this magnetized wire I pass a constant current of two bichromate cells, and at the same time an intermittent one, the spiral is increased to 15°, but the direction of the intermittent current entirely depends on that of the constant current; thus, if the positive of the constant current enters the north pole, the intermittent positive slightly in-

creases the spiral to 17°, and the negative to 13°, both being right-handed; the two zeros of the constant battery are, however, as we might expect from the preceding experiment, on equal opposite sides of the true zero; but if we magnetize the wire whilst a constant current is passing through it, a very great molecular disturbance takes place; loud sounds are heard in the telephone, and it requires for each current a movement of the coil of 40°, or a total for the two currents of 80°. This, however, is not the only change that has taken place, as we now find that both constant currents have a right-handed spiral; the positive under which it was magnetized a right-handed spiral of 95°; the negative, a right handed spiral of 15°, and the true central or zero point of the true currents indicates a permanent spiral of 55°.

This wire was magnetized in the usual way, by drawing the north pole of my magnet from the center to one extremity, the south from the center to the other, and this repeated until its maximum effects were obtained; in this state I found, sliding the coil to different portions, that the spiral currents were equal, and in the same direction throughout.

It now occurred to me to try the effect of using a single pole of the magnet; this was done whilst a constant current was passing through the wire, commencing at the extremity, where the positive joined, drawing the north pole through the length of the wire, from positive towards the negative; the effect was most remarkable, as the steel wire now gave out as loud tones as a piece of iron, and the degree on the coil showed 200°. The constant and intermittent currents now showed for either polarity a remarkably strong right-handed twist; the positive 200 right, and the negative 150 right-handed spirals; the molecular strain on its wire from the reaction of the electric current upon the molecular magnetism was so great, that no perfect zero could be obtained at any point, a fact already observed when a wire was under an intense strain, producing tertiary currents that superposed themselves upon the secondary. In order to compare these spiral currents with those obtained from a known helix, I found that taking a copper wire of similar diameter (0.5 millim.), and winding it closely upon the steel wire ten turns to each centimeter, having a total of 200 turns, with an exterior diameter of 1.5 millims., withdrawing the steel wire, leaving this closely wound helix free, that it gave some 190°, instead of the 200 of the steel wire alone; thus the spiral currents fully equaled a closely wound copper wire helix of 200 turns in a similar length.

If it were possible to twist a magnetized wire several turns to the right, and that its line of magnetism would coincide with that of the twist, then on passing a positive or negative current, there would be an apparent augmented or diminished spirality of the current, but both would have a right-handed twist. The result would be identical with the phenomenon described, although the cause is different.

The explanation of this phenomenon can probably be found in the fact that the constant spirality now observed is that of the electric current under which it was magnetized, for whilst magnetizing it we had a powerful source of magnetism constantly reacting upon the electric current, and the constant spirality now observed is the result or remains of a violent molecular reaction at the instant of magnetization, and the remaining evident path or spiral is that of the electric current. On testing this wire to its longitudinal magnetic force, I found that it was less than a wire simply magnetized in the usual way; thus the effects are internal, affecting the passage of the electric current, giving, however, no external indications (except apparent weakness) of the enormous disturbance which has taken place.

If, instead of drawing the north pole of the magnet as above, from positive towards negative, I draw it from negative to positive, all the effects are repeated, except we have now, as we should expect, a left-handed spiral, but if I draw the magnet from the extremities of the wire to the center, then at this center I find an absolute zero of twist, but on each side a contrary twist, the wire then having a left and right-handed twist, the positive traveling towards the center in a right-handed twist gradually ceasing in zero; this is as we might expect, but if done under the influence of a constant current, no mat-

ter what pole of the battery enters afterwards the north pole of the magnet, it will have during its first half a right-handed, and in its second a left-handed spiral. It became important to know if a wire, which had been magnetized under the influence of a current, could be restored to something like its original condition. Electric currents had no effect. Heat, which would not destroy its temper, had no effect. Mechanical vibrations and torsions failed to disturb the molecular arrangement; but by magnetizing it strongly by a magnet, when no current was passing, at once brought the wire to its usual apparently rigid state, and the constant or intermittent currents now indicated only 18° of spiral currents against a previous 200°, and the sounds were as usual, from steel, excessively weak. I have since used this method with invariable success, when I wished to preserve or repeat the experiments upon the same wire. If these experiments are repeated on an iron wire, the effects are far greater in the first instance, so great that they were thrown out of the range of my measurements; it was only after a few seconds of successive reversals that the zero of the wire was brought within range, and although these rapidly decreased, exactly similar effects were observed as in the steel, and as with all moderate ranges, I could bring the iron at once to a complete zero by torsion, and as torsion alone would produce this complete zero, I believe we have here effects from iden tical causes to those related in the first chapter.

Having noticed in my previous papers the increased molecular activity caused by the approach of a powerful permanent magnet, and believing that the permanent spirality above mentioned was due to this alone, and not to an increased polarity, I magnetized strongly an iron wire giving, as usual, a reversed spiral for different currents of but 10°. I now heated the wire by a spirit-flame to a dull-red heat, whilst the current was passing through it, and on cooling I found a similar but stronger permanent torsion of 250°; both currents, as in the previous experiments, have a right-handed spiral. Thus, a current of electricity passing through a wire, nearly red hot, determines molecular arrangement, or path, which, on cooling, forces currents of either direction to follow the path which had been determined under the influence of heat.

3. MOLECULAR SOUNDS.

The passage of an intermittent current through iron or other wire gives rise to sounds of a very peculiar and characteristic nature. Page, in 1837, first noticed these sounds on the magnetization of wires in a coil. De la Rive published a chapter in his "Treatise on Electricity" (1853) on this subject, and he proved that not only were sounds produced by the magnetization of an iron wire in an inducing coil, but that sounds were equally obtained by the passage direct of the current through the wire. Gassiot, 1844, and Du Moncel, 1878–81, all have maintained the molecular character of these sounds. Reis made use of them in his, the first electric telophone invented, and these sounds have been, since the appearance of Bell's telephone, often brought forward as embodying a new form of telephone. These sounds, however, for a feeble source of electricity, are far too weak for any applied purposes, but they are most useful and interesting where we wish to observe the molecular action which takes place in a conducting wire. I have thus made use of these sounds as an independent method of research, and by their means verify any point left doubtful by other methods, some of which I have already described.

The apparatus was the same as in the last chapter, except that no telephone was used. The intermittent electric current was connected by means of switch key, either with the coil inducing longitudinal magnetism in the wire, or could be thrown instantly through the wire itself, thus rapid observations could be made of any difference of tone or force by these two methods; a reversing key also allowed when desired a constant current of either polarity to pass through the wire under observation.

Iron, of all metals that I have yet tried, gave by far the loudest tones, though by means of the microphone I have been able to hear them in all metals; but iron requires no microphone to make its sounds audible, for I demonstrated at the reading of my paper, March 31st,

that these sounds with two bichromate cells were clearly audible at a distance. A fine soft iron wire (No. 28) is best for loud sounds to be obtained by the direct passage of the current, but large wires (1 millim.) are required for equally loud tones from the inducing coil. By choosing any suitable wire between these sizes we can obtain equal sounds from the longitudinal magnetism or direct current. The wire requires to be well annealed; in fact, as in all preceding experiments, the sounds are fully doubled by heating the wire to nearly red heat. There are many interesting questions that these molecular sounds can aid in resolving, but as I wish to confine the experiments to the subject of the two preceding chapters, I will relate only a few which I believe bear on the subject.

On sending an intermittent electric current through a fine soft iron wire we hear a peculiar musical ring, the cadence of which is due to that of the rheotome, but whose musical note or pitch is independent both of the diameter of the wire and the note which would be given by a mechanical vibration of the wire itself. I have not yet found what relation the note bears to the diameter of the wire; in fact, I believe it has none, as the greatest variation in different sizes and different conditions has never exceeded one octave, all these tones being in our ordinary treble clef, or near 870 single vibrations per second, whilst the mechanical vibrations due to its length, diameter and strain vary many octaves.

I believe the pitch of the tone depends entirely upon molecular strain, and I found a remarkable difference between the molecular strain caused by longitudinal magnetism and the transversal or ring magnetism produced by the passage of a current, for if we pass the current through the coil, inducing magnetism in the wire, and then gradually increase the longitudinal mechanical strain by tightening the wire, the pitch of the note is raised some three or four tones (the note of the mechanical transversal vibrations being raised perhaps several octaves); but if we tighten the wire during the passage of an electric current through it, its pitch falls some two or three notes, and its highest notes are those obtained when the wire is quite loose. A similar but reverse action takes place as regards torsion; for if the wire is magnetized by the coil we obtain an almost complete zero of sound by simply moving the torsion index 45° on either side, and as this was the degree which gave silence in the previous experiments for the same wire, it was no doubt due to the same rotation of its polarized molecules. If we now pass a constant current through the wire whilst the intermittent one is upon the coil, we hear augmented sounds, not in pitch, but loudness, and if we give torsion of 45° to one side we have silence, or nearly so, whilst the other side it gives increased tones which become silence by reversing the battery. If, whilst the wire by torsion has been brought to zero, we decrease or increase the mechanical longitudinal strain, then at once the polarized molecules are rotated, giving loud sounds; and we further remark that when the wire is loosened, and we again tighten it, we gradually approach a zero, and on increasing the strain the sounds return; thus we can rotate the molecules by a compound strain of torsion and longitudinal strain.

If we wish to notice the influence of a constant current passing through the wire under the influence of the intermittent current in the coil, we find that if the wire is free from torsion that on passing the current the tones are diminished or increased according to the direction of the current; the tones then have an entirely distinctive character, for whilst preserving the same musical pitch as before, the tones are peculiar, metallic and clear, similar to when a glass is struck, whilst the tones due to longitudinal magnetism are dull and wanting in metallic timbre. If we now turn the index of torsion upon one side, we have a zero of sound with or without the current; but the opposite direction give increased tones whilst current is passing through the wire, but zero when not. Here again a peculiarity of timbre can be noticed, as although we have loud tones due only to the action of the current through the wire, the timbre is no longer metallic, but similar to that previously given out by the influence of the coil; evidently, then, the metallic ring could only be due to the angular polarization of the molecules, and when these were rotated by torsion the tones were

equally changed in its action upon the wire.

I have already shown that a permanent magnet brought near the wire could rotate its polarization, and it equally can produce sound or silence in these molecular sounds (during the time that the wire is at its zero of torsion, and a constant current sent through the wire as in the last experiment) we find that either pole of the natural magnet has equal effect in slightly diminishing the sound by an equal but opposite rotation from the line of its maximum effects; but if the wire is brought nearly to zero by torsion, then on approaching one pole of the natural magnet we produce a complete silence, but the opposite pole at once rotates the molecules to its maximum loudness, and on taking away the magnet we have comparative silence as before.

Heating the wire to nearly red heat by a spirit lamp increases the tones of longitudinal magnetism induced by the coil some 25 per cent.; but it has a much more marked increase on the tones produced by the direct passage of the current where they have more than 100 per cent. increase, and if we pass the intermittent current through the coil and constant through the wire, we find no direct rotation of the molecules by heat. Although an apparent rotation takes place if we by the required torsion first place the wire at its zero, then on the application of heat faint sounds are heard, which become again almost silent on cooling; this is simply due to the diminution by heat of the effect of the elastic torsion.

Tempered steel gave exceedingly faint tones, requiring the use of the microphone; but on magnetizing with a constant current, inducing spiral magnetism, the sounds became audible, some 15° sonometer against 175° for iron; thus the molecular rigidity of steel as observed by previous methods were fully verified.

I have mentioned only a few of the numerous experiments I have made by the three methods described, all of which, however, bear directly upon the molecular arrangement of electric conducting bodies. I have selected a few bearing directly upon the subject I have chosen for this paper.

I have, I believe, demonstrated by actual experiments which are easy to repeat, that:

1. An electric current polarizes its conductor, and that its molecular magnetism can be reconverted into an electric current by simple torsion of its wire.

2. That it is by the rotation of its molecular polarity alone that an electric current is generated by torsion.

3. That the path of an electric current through an iron or steel wire is that of a spiral.

4. That the direction of this spiral depends on the polarity of the current, or that of its magnetism.

5. That a natural magnet can be produced, having its molecular arrangement of a spiral form, and consequently reversed electric currents would both have a similar spiral in passing through it.

6. That we can rotate the polarized molecules by torsion or a compound strain of longitudinal and transversal.

7. That the rotation or movements of the molecules give out clear, audible sounds.

8. That these sounds can be increased or decreased to zero by means that alone have produced rotation.

9. That by three independent methods the same effects are produced, and that they are not due to a simple change or weakening of polarity, as when rotation has been incomplete a mere mechanical vibration has at once restored the maximum effect.

10. That heat, magnetism, constant electric currents, mechanical strains and vibrations, have all some effect on the result.

In presenting these results to the Royal Society, I desire simply to draw attention to the effects that molecular action can produce in its relations to electricity and magnetism, and it seems to me that a knowledge of the molecular actions taking place is a necessary step previous to knowing what magnetism is in itself.

A new locomotive with a "patent steam reverse" is being finished at Reading, Pa., for the Philadelphia and Reading Railroad. This, it is said, will be the first locomotive ever built in Reading with an attachment for reversing the engine by steam instead of by hand.

THE IMPURITIES IN WATER, AND THEIR INFLUENCE UPON ITS DOMESTIC UTILITY.

By GEORGE STILLINGFLEET JOHNSON, M. R. C. S., F. C. S.

From the "Journal of the Society of Arts."

There are some impurities found in the water of rivers, more especially in those rivers which, like that in the immediate neighborhood of this building, take their course through large towns, concerning which I shall have little to say this evening. I allude to organic impurities, the detritus of living beings, sewage, and the like, and my reason for keeping silence upon this great subject is the incompleteness of our knowledge regarding it. Our highest medical authorities seem to be at variance as to the nature and degree of the baneful influence exerted by those impurities which I have mentioned upon the human economy, with the exception of the so-called specific poisonous products of such diseases as typhoid and cholera; and our highest chemical authorities are very much at variance as to the best method of estimating or determining the amount of these organic pollutions in waters, as they also are in the various accounts they give of the processes by which nature removes them. It would ill become me, therefore, to do more than hint at the existence of this source of contamination of water, unless I stood prepared to bring forward some new facts or experiments throwing light upon the subject, which I am not in a position to do. I must, therefore, confine myself this evening to the discussion of some of the more important inorganic impurities contained in natural waters, and their influence upon the domestic utility of the important liquid which contains them.

The word "impurities" has occurred several times already in this paper. I have also spoken of "pollutions" and "contaminations," all of which expressions tend to convey the idea that the presence of substances so described, in the water we drink and employ for household purposes generally, must needs be injurious and prejudicial. Now, the tendency of this paper will rather be to show the great usefulness of many of these so-called "impurities" in natural waters; and the word is used here in its strictly chemical sense, to indicate anything which we find in and accompanying water which is not the chemical compound, H_2O.

Pure water, the compound containing two atoms of hydrogen combined with one atom of oxygen, is a pure chemical substance which is never found in nature. We explain this by the statement that water exerts a solvent action upon various gases and solids.

It is, then, by virtue of its solvent action that water becomes impregnated with the impurities of which I am to speak; and I will, therefore, ask you to follow me while I make a few preliminary remarks upon, and show you a few experiments illustrating, the nature of solution. The process of solution consists essentially in a change of physical state, without alteration of chemical constitution. Thus, when sugar or common salt is dissolved in water, we can obtain the solid sugar or chloride of sodium by simply evaporating the water; and these are instances of true solution; but, if metallic copper be dissolved in nitric acid, that is an instance of solution accompanied by chemical change; for, if we evaporate the blue liquid thus obtained, we have a deposition, not of metallic copper, but of nitrate of copper, the salt formed by the chemical action which takes place between that metal and nitric acid. Solution proper, then, consists in a change of physical state simply without change of chemical constitution. Now, we know of but three physical states in which matter can exist, the solid, the liquid and gaseous. The solvent or substance which brings other substances into solution is usually a liquid. The dissolved body may be either a solid or a gas.

Now, the physical state in which we find any substance depends to a great extent upon the nature and intensity of

the physical forces which happen to be acting upon it at the time. Besides the action of solvents, the two physical forces, heat and pressure, exert a powerful influence upon the physical state of matter. The essential difference between the three physical states of matter is one of the relative freedom of motion which exists between the molecules or ultimate particles of which the matter consists, the gaseous form of matter possessing the greatest, whilst the solid possesses the smallest degree of molecular mobility. Heat, on the one hand, increases this mobility of the molecular of matter, whilst pressure has the reverse effect.

Next, observe that the solvent (liquid water, *e. g.*) is in the intermediate condition, as regards molecular mobility, between the solid and the gas, whose physical state it must assimilate with its own before it can bring them into solution. It follows, then, that the liquid solvent must bind a gas in chains, as it were, must diminish the free mobility which exists among the particles of that most elastic form of matter, whilst it will have to increase the molecular mobility of the comparatively sluggish solid, in order to make them respectively assume its own physical state. Accordingly, we should expect to find that a liquid will have its solvent action upon solids increased by the application of heat, whilst its power of dissolving gases will be diminished by heat, but improved by pressure. And these laws are obeyed in almost all instances.

I will now show you one or two experiments, to illustrate these preliminary remarks upon solution. When I stir up these two white powders in separate beakers of hot distilled water, you observe that one of them (which is powdered sugar) becomes readily incorporated with the water, changes its physical state, assuming that of its solvent, is dissolved. That is an instance of a soluble substance. This other powder, however, refuses to do anything but remain partially suspended in the water, making the liquid look milky, whilst the greater part of it (for it is very heavy) sinks and remains at the bottom of the beaker. It is the salt called sulphate of baryta, and is one of the most insoluble bodies known.

To illustrate the effect of heat in assisting the solution of a soluble solid substance in a liquid, it will be sufficient to cool this hot saturated solution of iodide of lead, when we find that water, which was capable of retaining a large quantity of that salt in the liquid state whilst hot, becomes incapable of doing so as it cools, and the excess of salt separates out from the solution in the chrystalline form.

To demonstrate the action of heat in retarding the solution of a gas in a liquid, I will first pass up a little water into this tube (which contains dry ammonia gas confined over mercury). As soon as the water reaches the gas, you see that the latter disappears, being dissolved by the water. Now, if I pour a little hot water over the outside of the tube, we shall soon see the effect of heat in increasing the molecular mobility of the ammonia, for the restraining power of the water, at this high temperature, becomes insufficient to control the elasticity of its volatile companion, and the ammonia bursts its chain and resumes the gaseous condition. As the tube cools again, the solvent power of the water is again triumphant, and the gas disappears. Not only does the temperature of the liquid solvent exert an influence upon the quantity and quality of the substances which it is capable of dissolving, but the solvent action of a liquid is often considerably modified by the presence therein of subtances which it has already dissolved.

We will consider this influence of dissolved matter in water upon its solvent action on other forms of matter somewhat fully, since it serves to explain the presence of some of the impurities found in waters; and it will be convenient to divide the subject into two heads, viz.:

1. The influence of dissolved gases upon the solubility of solids.

2. The influence of dissolved solids upon the solubility of other solids.

1. Excluding those cases in which a chemical action occurs, resulting in the production of some insoluble compound by the action of a dissolved gas upon one or the other of the elements present in a dissolved solid, the general tendency is for a dissolved gas to increase the solubility of solids in their common solvent. As an illustration of this, I will cover this solution of copper sulphate with a strong solution of ammonia gas in water.

You see now three layers in the containing vessel. Below the blue solution of copper sulphate, above the colorless solution of ammonia gas in water, and between the two, a light blue turbid layer, the turbidity of which is due to the presence there of suspended hydrated oxide of copper, a substance which is insoluble in pure water, and in most neutral and alkaline solutions, but which is soluble in a solution of ammonia gas in water, yielding a dark blue liquid, which you see is produced when I stir up the contents of the beaker. There are other instances which will occur to every chemist, of solid bodies quite insoluble in pure water, yielding to the solvent action of a solution of ammonia gas in water. It appears, then, that the dissolved gas confers a degree of molecular mobility upon the water which has dissolved it, or at least enables that water to produce the requisite freedom of motion amongst the molecules of an otherwise sluggish solid, which is necessary in order to compel it to assume the liquid state.

2. It is frequently observed, and especially amongst the halogen group of elements, that an insoluble salt is rendered soluble by the presence in their common solvent of a very soluble solid body. One of the most striking and beautiful examples of this is seen in the case of the red mercuric iodide, which is entirely insoluble in pure water, but is readily dissolved by water saturated with potassic iodide—a very soluble salt. It is essential that the potassic iodide be present in a somewhat concentrated solution, for, as you see in this beaker, when a solution of mercuric iodide in one of potassic iodide is mixed with a large bulk of pure water, the red mercuric iodide separates out. If there be any chemical action between the two iodides in this case, it is of the very feeblest kind. Indeed, some experiments of my colleague, Mr. J. M. Thomson, have tended to show that, if the double salts formed by dissolving insoluble halogen compounds in soluble ones be compounds at all, they are molecular, not atomic combinations. It is, at all events, interesting to remark, that when a dissolved solid assists the solution of another solid body, it is the more soluble substance—that which is endowed with freest molecular mobility—which serves to bring about the liquefaction of the more sluggish solid; and there are instances of this action which cannot be at all explained by chemical action, as in the case of the solubility of quick lime in a strong solution of sugar.

It sometimes happens that the action of a solvent is arrested by the formation of a protecting film of an insoluble substance upon the surface of an immersed solid. Thus, marble, which is a compact crystalline variety of carbonate of lime, is freely dissolved by a solution of hydrochloric acid gas in water, the only solid product of the accompanying chemical action being the salt known as calcic chloride. Now, calcic chloride is freely dissolved by water, and, as each particle of it is formed on the surface of the marble, it is dissolved off by the water, and fresh surfaces of marble are constantly exposed to the action of the hydrochloric acid. But, if we immerse marble in water containing both hydrochloric acid and sulphuric acid in solution, its surface speedily becomes covered with an insoluble film of calcic sulphate, and the action ceases. Marble is still there in abundance; hydrochloric acid is also present in quantity, adequate and sufficient for its solution; but, by reason of the intervening insoluble film of calcic sulphate, they are prevented from acting upon one another. "The chemical force can only act at infinitesimally small distances." Another instance of the protecting action of an insoluble film upon the surface of an otherwise soluble solid is seen in the case of the black ferrous sulphide. When this substance is acted upon by sulphuric acid, the salt known as ferrous sulphate is produced. Now, green vitriol, or ferrous sulphate does not dissolve in cold, strong sulphuric acid, but it dissolves readily in hot dilute sulphuric acid. When, therefore, I pour cold oil of vitriol over this ferrous sulphide, there is little or no action, a film of ferrous sulphate forming on the surface of the sulphide, and protecting the sulphide beneath from the action of the acid; but when I pour water into the containing vessel, a brisk action is at once set up, heat being developed by the admixture of the water with the acid, cold strong sulphuric acid being converted into hot dilute sulphuric acid,

which dissolves off the ferrous sulphate as fast as it is formed.

I will now pass on to a consideration of some of the impurities contained in natural waters—in water as it is supplied to us for use in every-day life—explaining, where that is possible, the sources and method of contamination, and, further, discussing the chief precautions necessary for the removal of such impurities as are prejudicial to the domestic utility of this valuable agent. First, then, we will consider the gas found in solution in natural waters, with some trifling exceptions, viz., some of the rarer mineral waters, the gases dissolved in water are those which are present in our atmosphere—oxigen, nitrogen, carbonic acid, and ammonia. The oxygen and nitrogen gases, the elementary constituents of the atmosphere, are present in it in invariable quantities, and are far less soluble than the other two.

The carbonic acid and ammonia, or compound gases, are chiefly products of animal life, and are constantly being removed by plants and vegetable organisms, but they are also more soluble in water than the first two. The carbonic acid is present in larger proportion than the ammonia, whilst it is also far less soluble than the latter gas. Indeed, after a long continued fall of rain, the presence of ammonia in the air of a place is hardly recognizable.

Spring waters are very apt to contain much larger quantities of CO_2 than rain water or river water. Meandering, as they frequently do, through subterranean passages, they are exposed in their course to influences peculiarly favorable to their conversion into strong solutions of this gas. The earth being the common receptable for dead organic matter, and her cavities being in many cases never penetrated by the sun's rays, or ventilated in any way, accumulations of carbonic acid are to be expected in these regions. The water, then, which is often very cold (it may be produced by melted snows), is churned up at frequent intervals along its course with these terrestrial gases, and becomes, in consequence, highly charged with them.

We are able to demonstrate the presence of dissolved gases in water, by simply boiling it in an apparatus such as this which I now show you, and collecting the permanent gas which escapes, as is being done here. The presence of these dissolved gases in water appears to be in every way beneficial. If we consider water as a beverage, the sparkling and refreshing effect of spring water is largely due to the dissolved gas, especially to the carbonic acid gas which it contains. Again, boiled or distilled water, from which the gases have been expelled by heat, is mawkish and insipid, but may be again rendered palatable by aerating it with charcoal. But more than this, absolutely gas-free water (which, however, can only be obtained by boiling water in vacuo), boils at a temperature considerably above 100°C., and with violent explosion.

Again, it is probable that the oxygen dissolved in water oxydizes, and removes some of the more readily putrescible organic matters contained therein; and it certainly is of the utmost importance to the life of fish. The dissolved gases in water also exert an important influence upon its solvent action for solids, as we shall now find. The solid substances dissolved in waters are generally chlorides, sulphates, and carbonates of the alkalies, and of the alkaline earth metals.

Those waters which contain the alkaline earths in solution, are divided into (1) calcareous and (2) magnesian waters, the former containing sulphate or carbonate of lime in solution, the latter sulphate or carbonate of magesia. Such waters are said to be hard. Now, it is in the case of the carbonated calcareous and magnesian waters that we observe most distinctly the influence which a dissolved gas may exert in modifying the solubility of a solid in their common solvent. For the carbonates of lime and magnesia are insoluble in pure water, or nearly so; but considerable quantities of these salts may be brought into solution by water charged with carbonic acid gas. For instance, if I bubble carbonic acid gas through this clear lime water, we first observe a milkiness, due to formation of the insoluble carbonate of lime; and on continuing to pass the gas, we finally obtain a clear solution. The dissolved gas enables the water to overcome the molecular sluggishness of the calcic carbonate, and to reduce it to the liquid condition; just as the dissolved ammonia gas in our previous experiment

enabled the water to hold in solution the hydrated cupric oxide. Now, if I boil this clear solution of bicarbonate of lime, the excess of gas is expelled by the heat (just as the ammonia gas was expelled from its dissolving water when the temperature of the tube containing the solution was raised), and the water, no longer aided by the mobile carbonic acid gas, loses its power of keeping the calcic carbonate in the liquid state; accordingly that salt is reprecipitated.

Bearing the facts in mind, we shall be able to explain some of the phenomena of nature in connection with this subject of calcareous waters. We have seen that spring waters are frequently highly charged with carbonic acid gas; now carbonate of lime, in the shape of chalk deposits and limestones of various kinds, is a very constant ingredient of the soil in many parts of the earth's surface. It must, therefore, be a matter of very frequent occurrence for water, already highly charged with carbonic acid gas, to come in contact with carbonate of lime in the course of its subterranean wanderings; hence the frequent contamination of natural waters with dissolved carbonate of lime. But there is another interesting and very beautiful phenomenon which we are enabled to explain by the light of the above facts. I mean the formation of stalactites and formations such as are figured in the diagram on the wall. Suppose a water holding in solution much carbonate of lime and carbonic acid gas to trickle slowly through the roof of a cave. From each drop of water, as soon as it finds itself exposed to the common air, some of its dissolved carbonic acid gas will begin to evaporate, and for each molecule of gas which thus leaves the water, a molecule of calcic carbonate will be deposited in the solid form. Let a few of these solid particles adhere to the roof of the cavern, and from the nucleus thus formed, the production of vast conical masses, such as are here portayed with their beautiful tapering apices pointing towards the earth, is only a matter of time. The nature and quantity of the dissolved salts in spring water will, of course, vary with the composition of the soil through which it has passed. Many mineral waters are of great medicinal value.

We will next consider the influence of dissolved lime salts upon the domestic utility of water. Is "hardness" in water prejudicial? If we consider the water as a beverage, the answer would be, No, The worst that hard waters have been accused of is that they produce a tendency to calculous formations in those who drink them. But I think the water drinker may answer to that charge, "Not proven." And, on the other hand, we cannot but remember that the metals calcium and magnesium, in combination with phosphoric and carbonic acids, play the important part of conferring the requisite degree of hardness and stability to our frame—are, in fact, the earthy constituents of the skeleton. But there is another purpose for which water is employed, viz., for washing, and which is hardly less important than that we have just considered. For this purpose hard water is certainly disadvantageous.

Soap contains fatty acids, which form insoluble compounds with the lime and magnesia in hard waters, and no lather will be produced till all the lime and magnesia dissolved in the water have been precipitated in this way. And this occasions a waste of soap.

Now, what is called the temporary hardness in water may be removed by boiling it. The expulsion of the dissolved carbonic acid gas by that means, leads to the removal of the calcic carbonate from solution in the water, and the hardness due to that cause is then removed. But the water may contain sulphate of lime in solution, which will not be removed by boiling the water. On the contrary, unless the water had been previously saturated with the salt, the evolution of steam in boiling would rather tend to concentrate its solution, and thus the permanent hardness due to this cause would remain. Moreover, there is a further objection to boiling water (except in small quantities) for the purpose of removing its hardness, since, besides the consumption of fuel which is necessarily incurred, the deposited calcic carbonate tends to form boiler incrustations, often of considerable thickness, upon the walls of the vessel employed for the purpose, and if they do not lead, as they have too often done, to dangerous accidents by their suddenly becoming detached, and producing explosive bursts of steam, by allowing the water to come

in contact with the strongly heated metal wall of the vessel, yet must invariably cause great waste of fuel, owing to their inferiority as conductors of heat. Therefore, the process of Mr. Clark, which is conducted without any application of heat at all, was a great boon to mankind, especially as it has the additional advantage of clarifying a water as effectually as any filter.

The problem before us is essentially this. How may dissolved calcic (and magnesic) carbonate be best removed from solution in water? *i. e.*, how may these salts be converted into suspended and insoluble matter with the smallest possible expenditure of time and money? We have seen that the method of boiling the water, though effectual, is objectionable on the score of expense, liability to accidents, &c. Now, in Mr. Clark's process, which I have said is preferable, the suspended insoluble calcic carbonate produced has to be removed by subsidence. There are two methods by which suspended matter is removed from water in nature, subsidence and filtration, and these processes are also adopted by man for the same purpose. Now, it is claimed for the method of purification by filtration that organic matters are oxidized by the substances employed, *e. g.*, charcoal, which has the property of retaining oxygen gas in its pores. But the process of Mr. Clark also undoubtedly removes dissolved organic matters from waters, the lime which is added acting as a mordant, and producing their precipitation. Mr. Clark's process is as follows: By adding quick lime or hydrated (slaked) lime to a carbonated calcareous water, the carbonic acid gas which is holding the carbonate of lime in solution, is first removed by combination with the added lime, and the carbonate of lime thus produced falls, together with that previously in solution, as a solid insoluble precipitate. The turbid water is left to clear by subsidence, and is afterwards drawn off freed from temporary hardness.

I have hitherto been speaking of what may be called unavoidable impurities in water—impurities, viz., which are introduced by natural processes which are beyond the control of man; but before concluding, I must allude, however briefly, to a very important accidental source of contamination of water, which is sometimes introduced by man himself, I mean the contamination of water with lead. And here we shall find that the influence of dissolved matters in any water is extremely important in modifying its solvent action upon this metal. Lead, from the ease with which it is worked, and the resistance which it offers to atmospheric action, changes of temperature, &c., has been found to be a very convenient metal wherewith to construct pipes for conveyance of water, and cisterns for its storage. But lead is dissolved in appreciable quantities by some natural waters, and the long-continued ingestion of that metal, even in very minute quantities, produces serious symptoms of disease in the human subject, so much so that the metal has given its name to at least two specific affections, lead colic and lead palsy. It becomes, then, a matter of the utmost importance to be able to state, from a knowledge of the ingredients of any given water, whether or not it will be safe for persons to drink that water after it has been stored in leaden cisterns—whether or not that particular water is likely to exert any solvent action upon the metal. This we are able, in many cases, to do. For it has been found that pure water, free from both dissolved solids and gases, has no solvent action upon lead. But water containing dissolved oxygen becomes impregnated with lead, oxide of lead being, to a certain extent, soluble in water.

1. Practical Deduction—Rain water, stored in lead, must not be used for drinking purposes. Again, when waters containing carbonates, and especially sulphates, in solution are stored in leaden cisterns, the metal becomes coated with an insoluble protecting film of carbonate and sulphate of lead, further action being thereby prevented, and the water does not become saturnine.

2. Practical Deduction—Carbonated and sulphated calcareous waters may usually be stored in lead with impunity. The film which forms on the surface of the metal should by no means be removed.

3. Waters containing nitrates and chlorides in abundance cannot safely be stored in leaden cisterns, since the nitrate and chloride of lead are soluble salts. The practical deduction from this is obvious.

In concluding, I hope I have convinced most of my hearers that though we do not drink pure water, it would be very much worse for us if we did, and that, whilst we may sometimes be inclined to ask, "Why is such a substance here?" we generally find at last that it serves some important purposes which had escaped our ken—in fact, that we are finally led to wonder at the Wisdom which works through intricate and complicated labyrinths to a perfect and simple end, and are forced to admire the ultimate tendency and result of even such seeming anomalies as the "impurities in water."

THE USE OF MARBLE AND SIMILAR MATERIALS IN ENGLISH ARCHITECTURE.*

From "The Building News."

The subject of my paper is the use of marble and similar materials in English architecture. Among these materials I include all those stones which have a slight degree of translucency and will take a polish, and which are valued in architecture either for their beauty and variety of color—as, for instance, the veined and breccia marbles, porphyries, serpentines, and some kinds of alabaster—or else for their delicacy and purity, and the closeness and fineness of their texture, as in the case of statuary, Parian, and white alabaster. I have chosen this subject because the opportunity we Englishmen have now for using materials of this kind in our work is something novel in English architecture, and because, unless we recognize this novelty, and try to ascertain the proper principles by which to employ this new material, we are not likely to employ it well. It is true that it was not an unknown material in Mediæval England. This could hardly have been so, for in Devonshire it is a common building stone, and every shower of rain makes the smooth flagstones of Plymouth look like slabs of polished marble. It would be more correct to say, that, though not unknown, it was almost ignored. And it was ignored not so much from choice as from necessity. M. Viollet-le-Duc observes that in France, where the use of marble during the Middle Ages was as rare as with us, if not rarer, romancists were fond of writing of marble palaces, and so forth, and that the chroniclers of the Abbey of St. Denis boast of the marble columns with which Abbe Suger surrounded the choir, which, however, turn out, after all, to be only of stone. It is most probable that the expense and delay of working marble was the real reason why it was neglected in a style which was the child of economy, and in an age when labor was costly and laborers few. However this might have been, in the earlier styles of our native architecture it is the fact that, with the exception of the simple grey marbles of Purbeck and others like them, which were employed chiefly in shafts, the use of marble was neglected. In the later periods of Gothic art, alabaster, which is soft and easily worked, came into use for monuments and reredoses, and similar small works; and, still later, marble was used a good deal in our English Renaissance, though even then chiefly in small work, such as monuments and chimney pieces. The marbles then employed seem to be chiefly foreign, and to have been regarded as a rarity and used with economy. It has been reserved to our own age, when steam transport by land and sea has relieved us of the necessity of using only local materials in our works, and when provincialisms in architecture seem destined to give way before a more general interchange of materials and modes of workmanship, to have marble brought to our doors so easily, and in such quantity and variety, that it fairly takes its place as one of our building materials.

Now, to those who take what I believe to be the right view of our position in the history of art—who recognize the fact that we live in an age which is necessarily eclectic; building up for ourselves

* A Paper read before the Architectural Association by T. Graham Jackson, M. A.

an art out of the teaching, not of one only, but of many bygone styles, all more or less unsuitable—and who look forward to the development, in due course, of a really modern art which will represent us better—the acquisition of a new material will be welcome as opening the way for a fresh departure in our practice. For every special need of our life which is met and satisfied, and every new material which is adopted and put to its proper use, must involve some modification of the adopted styles we work in; and each such modification, if made in accordance with true artistic principles, or, what is much the same thing, common sense, must result in genuine progress. There is no need to urge the use of marble on modern architects. Ever since it has been easy to have it, there has been no lack of demand for it, and this is not wonderful. The first impulse seems to have been given by the books of Mr. Ruskin and Mr. Street. Delighted to find himself allowed, and even encouraged, to indulge himself in the study of a branch of Gothic architecture which had been forbidden by the sterner masters of Gothic purism, the student rushed to Italy and found there wonders of color and exquisite finish of workmanship for which his Northern training had in no way prepared him. Accustomed to regard a 4-in. marble shaft as an extravagance, and an alabaster pulpit or font as a matter for glorification, he suddenly found himself in a country where marble was used as a common building stone. The sensation with which, for the first time, one stands in an Italian church, such, for instance, as that of St. Lorenzo at Genoa, where arches and walls of banded black and white marble are carried on closely serried ranks of massive columns of deep purplish red, is one of astonishment mixed with incredulity. And as the student travels further and becomes accustomed to see marble used universally for purposes where, in his less-favored land, common stone would have been employed, his satisfaction grows in proportion as his wonder lessens. To many students after an Italian tour—at all events, a *first* Italian tour—the return to sober stone is like disenchantment, and it is no wonder that they seize every opportunity of using the material which has charmed them under an Italian sky. With this desire I have no wish to quarrel. We may safely welcome the new material and use it freely, provided we learn to use it properly and do not forget that it *is* a new material in English architecture, and that as a simple consequence its adoption must bring with it new methods and principles of design.

I propose to-night to touch successively on a few of the principles of design by which the effects which we admire in the marble work of the past have been produced; and to show how, by the neglect of these rules, we moderns have constantly failed to succeed in making the most of our new material; and how we have sometimes even spoiled what might otherwise have been tolerably good work, by the improper use of a material which would have improved it had it been judiciously employed.

The first thing to be insisted on is that marble is not, as some seem to think, merely a more beautiful kind of stone, which may be used just where and how we might use stone, but with a correspondingly more beautiful effect. Marble has other differences from ordinary stone than its superior beauty. In the first place, it is generally much harder, and to work it involves infinitely more labor; in the next place, it has a slightly transparent quality, which requires special kinds of design to make one's work upon it tell distinctly; and again, in the case of colored marbles, we have a totally new field of design opened to us differing from any that mere stone masonry offers. All these points involve new considerations to one who has been trained exclusively in the Northern schools of Gothic architecture, which are distinctly stone styles. Their deeply-recessed orders, undercut mouldings, and elaborate traceries, the highly-relieved character of their decorative sculpture, especially the naturalism of some of it, are all derived from the use of stone, and are appropriate only to a soft, easily-worked material. There is nothing here to teach us how to make the best use of our new material. It is only from those who have been used to work it that we shall learn how to deal with it, and it is, therefore, to Italy that the student must look for instruction. In that country marble has always been a possible and

the favorite material, and the true principles of working it have never been entirely forgotten. From the time when the Gothic or Lombard builder first began to carve rude marble capitals of his own by the side of those he pilfered from the ruins of antiquity, down to the time of the Renaissance, when perfect knowledge and unrivaled skill in dealing with marble seemed to make that stubborn material as plastic as clay in the artist's hands, we find it employed sensibly and with proper economy—by which I mean that no labor was unprofitably spent on it, and that the workman succeeded in producing the desired effect with the least possible fatigue. The principles of work according to which this result has been obtained are simply those by which every good school is guided; they are the same which, working under different conditions, produced the totally different styles of France and England. Decorative sculpture north of the Alps owes its character to the stone in which it was cut, and that south of the Alps to the marble in which it was cut, because in both styles the workman recognized and respected the qualities of the material he was at work upon, and as he worked in the direction which these qualities suggested to him, his work fell naturally into such a shape as best brought out the beauty of his material with least labor to himself. For instance, the first consideration of a sculptor or mason in marble would naturally be the hardness of it, and the time his work would occupy him. Every deep line in the foliage of his capitals would have, first of all, to be drilled out with a succession of holes, which would afterwards be joined together by the chisel into a regular sinking. This laborious effort is of itself enough to confine the carver to a stiff and regular mode of design. Of what use would it be to him to think of imitating the wild freedom of the stone-carved capitals of the North, which have all the rapidity and boldness of sketch, where we see that a few vigorous blows have sufficed to give a depth of shadow that it would take a week to produce in marble, and where there is an easy play and variety of line that can only be had where the chisel travels easily and freely, and finishes at once? To imitate this free work in a stubborn material is an artistic mistake of the first order, of which examples are not wanting even in old work. Most of you may be acquainted with the spiral colonnettes in the north and south portals of Chartres Cathedral, which support, if my memory is correct, the statues lining the jambs. The hollows of these twisted shafts are stopped by exquisite little bunches of leaves carved with a freedom and grace that have seldom been surpassed. They were evidently struck off in a happy vein, and quickly finished while the mood lasted. Those of you who have seen the front of Orvieto Cathedral may remember the spiral shafts of the doorways with their lovely mosaic inlay. The architect has there tried a similar plan of laying natural leaves at intervals in the hollows of his shafts, but with a far less satisfactory result. The freedom of the French example is entirely wanting. The leaves look labored and heavy and leathery, for they took so long to work that all the zest of the original idea evaporated before they were one quarter finished. To illustrate the difference between the two modes of work in the two materials, I may turn to the difference between an etching and an engraving. The etcher's needle travels sweetly and smoothly over the varnished plate. He can sketch as he goes on, with the utmost freedom, and finish his work a hundred different ways, whereas the engraver has laboriously to plough out line after line, to lay them parallel to each other, and to work evenly, regularly, and methodically. Just so the marble carver. He must lay his lines firmly and positively in their right places, and work them out slowly and painfully. There is no rapid sketching for him; and therefore he cannot hope to succeed in those designs which answer best with rapid handling. In this I believe we find one key to the greater conventionalism of the decorative carving of Italian art, and perhaps even to that of Classic art itself. The stiffness of material led to stiffness of design, except in cases where labor could not be misapplied nor the sculptor's interest exhausted, as in the human figure. It would not be wearisome to carve a block of marble into a Corinthian capital, or one of those conventional capitals of the Early Renaissance, of which there is such an in-

finite variety, because its very regularity and symmetrical perfection precludes the idea of its being done otherwise than with care and pains, and in a considerable time. You are in no hurry to embody your idea before it escapes you, for you have laid down your outlines correctly from the first, and have only to fill them up. It is natural that work such as this, which takes a long time and considerable labor, should bear the stamp of laboriousness, careful arrangement and perfect execution, rather than that of facility and freedom; and when the mechanical labor is so great as it is in the case of marble, it is natural that a great part of the less important ornament into which it is worked should be mechanical too. Hence, no doubt, the frequency in marble of such conventional ornaments as the egg and dart, and similar enrichments of Classic mouldings, which occur in Italian work even during the Middle Ages. The freer design of Northern carving is enjoyable only so long as it can be cut freely, and to carve it in marble would be tediousness itself in comparison with carving the more conventional ornaments I have named. There is, however, a free outlet for naturalism in marble, of which neither the ancient nor the modern Italians have failed to take advantage. It lies in the opportunity of working in low relief. In common stone considerable relief is generally necessary, partly because most stones have a coarseness of grain which interferes with a very delicate finish, and partly because even if the stone is fine enough it is seldom so hard as to make a low relief durable enough to resist ordinary wear. But marble is so fine of texture that every touch tells, and so hard that the smallest amount of relief may be safely trusted to last. I think no decorative sculpture shows more astonishing ability and more perfect appreciation of the material employed than some of the slighter reliefs of Italian art. Efforts of perfect solidity and modeling are produced with the relief of a bare $\frac{1}{4}$-in., and some of the finer lines are actually not relieved at all, but marked by a slight sinking of the ground or incising of a line round them. Here the labor is in comparison slight, and in the arabesques which cover the surface of the monuments of the Renaissance there is the utmost ease and grace and freedom of line, and often the most charming naturalism. But, above all, the Italian found room for naturalism in the representation of the human figure. There the labor required by the material suits the nature of the subject. In figure carving there is no room for hasty suggestive work; all must be complete and well studied, and finish can hardly be carried too far. The superior artistic value of the work also seems to demand the most durable of materials, marble or bronze, and to repay any expense of time and labor. There is no fear of the artist tiring of work that he feels to be worth the trouble he bestows on it.

I turn now to another property of marble which distinguishes it from stone—its variety of color. This introduces us to entirely fresh considerations, even more foreign to our native styles of architecture than those of which we have been speaking. At the beginning of this paper I distinguished two uses to which marble can be put and for which it is valuable: 1. The beauty and variety of color of some kinds. 2. The compactness of texture and simplicity of color of others. Now, though from one point of view we are in either case dealing with the same class of materials, from another point of view we are dealing with materials of two totally distinct kinds. They are distinct as the beauty of form is distinct from the beauty of color. This is so simple a distinction that it seems at first sight hardly worth enunciating, and yet there is no more common error than to confuse it. Marble that is valuable for its color is valuable for that alone. Nothing else ought to be present to our minds when employing it. To carve it is, except in very rare instances, a monstrous violation of the first principles of art. If, then, a marble, besides being colored, has any *variety* of coloring, it is absurd even to work mouldings on it; and yet this is a thing that is done every day. The architect wants a marble base or capping, and fixes his affections on a lovely block of breccia mottled with yellows, reds and blacks, on a nearly white ground; or a scarcely less beautiful piece in which white and colored veins cross and recross one another or lie obliquely along the surface. On this he works the rolls and

hollows of his base, or the details of his cornice, and is disappointed to find the result is not equal to his anticipations. The lines of the coloring contradict and confuse those of the mouldings. One does not know which to look at, the lines drawn by nature or those cut by the chisel. The level lines which are necessary in such features for the proper architectural effect are upset by the irregular markings of the material, and the beauty of the markings themselves is destroyed by their being broken into by the mouldings, which distort them just as a drawing is distorted when rolled up. The mistake is simply this, that the radical difference between designing for form and designing for color has been ignored. The effect is almost as bad when strongly-marked marbles, such as many of the Devonshire varieties, are used for steps. The effect of a flight of steps (and there are few more dignified features in architecture) depends on the regularity and evenness of the lines, and the simple alternation of light and shade in tread and riser. All this is destroyed by veins that run obliquely, and so distort the horizontal lines, or by strongly-massed colors, which interrupt the simple breadth of light and shade. In all the instances which I have given, the architect, caught by the beauty of the material, has thought that it would be sure to beautify anything he might use it for, and, having used it for an improper purpose, he ends by destroying both the form of the object and the beauty of the material. No material is worse abused at the present day in this respect than alabaster. Alabaster costs less than marble in the block, and being much softer, costs less in labor, and, consequently, is much cheaper as a material, and is, therefore, readily accepted as a substitute. With a little trouble it may be had quite white; but, as a rule, it is more or less strongly veined with warm brown streaks; and, strangely enough, it is this colored alabaster that seems most popular, not only for plain work, but for sculpture. The absurdest effect is sometimes produced by its employment for groups of figures in a reredos, when the brown streaks run undistinguishingly across the face of an apostle or the drapery of a saint, blurring the features of one and confusing the flowing lines of the other in the most distracting manner.

The plain rule for all kinds of varied marbles is that they should never be used except for their color, and in such a way as to make the most of their color. They should be used in flat slabs, inlaid in panels, like pictures, or used for lining the surfaces of walls or large compartments of pavements, always in large enough pieces to allow the variety of the markings to tell; for, of course, if they are cut up into small pieces they will differ but little from self-colored marbles. One very sensible way of using them is by splitting and reversing them, so that the veins and markings form regular figures, like the patterns formed by a kaleidoscope. This was very commonly done in Byzantine work, and may be seen at St. Mitale, Ravenna, and St. Mark's, Venice, and also, in later times, as in the palaces Vendramin Calerghi and Corner Spinelli on the Grand Canal, designed by the family of the Lombardi at the end of the fifteenth century. Perhaps the only lawful occasion for the use of variegated marble for actual parts of the architecture is that afforded by columns. Their form is so simple and clearly defined that the irregularities of the marble cannot confuse it, and the cylindrical surface is as well adapted for displaying the beauty of the markings of the marble as a flat surface would be. But such marbles should only be used for *plain* columns. If the columns were fluted the beauty of the material would be seriously diminished. The rule to employ a colored marble, for the sake of its color only, will, to a certain extent, apply also to self-colored marbles, which have no variation of surface. The instances in which sculpture can be successfully applied to any but white marble are very rare, even if they are admitted to exist at all. I do not forget the Egyptian figures in black stone, porphyry, or granite, nor the red marble lions that carry the columns of the Lombard porches in North Italy. But it may be observed that these are all archaic works that stand very low in the scale of sculpture, being conventional and abstract to a degree which we are not likely to imitate, and, indeed, could not imitate without affectation. But the prohibition

against the use of colored marbles for our more developed sculpture need not prevent us from working mouldings on it, for if the color be but uniform the mouldings are as well seen in one color as in another. or even as in white. For bases, cornices, architraves, and steps, therefore, there can be no objection to the use of marbles, such, for instance as the Veronese red, which is employed with such good effect in the north of Italy, or the black, which gives such dignity to many interiors in the Low Countries.

Whilst we are on the subject of colored marbles, I would touch upon another rule, and a most important one; that is, to work with moderation, and a limited palette. The same rule applies, more or less, to all decorative arts. The breach of it has done more to degrade modern glass painting than anything else. Seven tints of glass, I believe, sufficed the glass painter of the thirteenth century, and with them, and no more, he produced those miracles of gorgeous color which we see at Chartres, Bourges, and Canterbury. A similarly restricted palette was enough for the wants of the artists of the fourteenth and fifteenth centuries. The result was a harmony of color and a simplicity of composition that were admirably suited to the purposes of architectural decoration. The modern glass painters have, I believe, the choice of about 400 different tints, and many of them seem to avail themselves of the liberty of choosing without restraint, not with the happiest results. The only modern glass that is worth looking at has been designed on totally opposite principles, with but few colors carefully selected and artistically composed. And in the same way in the arrangement of marbles there can be no greater mistake than to use many varieties in the same composition. There are very few designs for which three kinds of marble would not be enough, or in which there would fairly be room for more. The marble screens of the Low Countries afford a good instance of the satisfactory application of this principle. One of the finest of them—now removed, unfortunately, from its original site in the Cathedral of Bois-le-Duc, and preserved, fortunately for us, in our museum at South Kensington—is an example of the kind of screen I refer to, of which there are scores in the great churches of the Netherlands and French Flanders, beginning with the old church of Notre Dame at Calais. In this magnificent structure there are but three marbles employed—black, white, and red—and they are used according to the principles I have endeavored to put before you. The white is used for sculpture, the black (which is of one simple tone) for the moulded architectural work, and the red, which is variegated, though of a very sober tone, for the columns.

There is another lesson to be learned from the practice of the best schools as to the usefulness of working with moderation and self-restraint in a material which offers so many temptations to over display as marble. The beauty of some of the variegated marbles is so great, and their colors so powerful, that they often exercise a seductive influence on those who have had little experience themselves in the use of marble, and have paid little attention to the practice of those who have had more. Caught by the splendor of these more gorgeous varieties, they neglect the soberer kinds, and they arrange their magnificent materials so as to produce the most powerful contrasts and the most gaudy combinations. No marble has been more popular in modern churches than a brilliant light-green Irish marble, which is in itself of an almost hopelessly impossible color to work with, but is often made still more offensive by being placed next a bright red. Such gaudy combinations as these are enough to vulgarize any design, and are quite at variance with the teaching of all the best achools, which employed not only very few marbles at a time, as I have just explained, but generally preferred those of soberer colors, and avoided strong contrasts. Indeed, when one is new to the study of Italian art, and when the first rapture at the wealth of marble that surrounds one is fresh, one is disposed at first to wonder why strong contrasts were so seldom resorted to, and why, when so many splendid marbles were to be had, the quieter specimens were preferred. A structure of white marble will often be relieved only by panels of pale breccia, as at the Giant's Staircase at Venice, selected evidently for their light color

and amount of white ground. At the Scuola di San Rocco, one of the most lovely and refined works of the early Renaissance, the principal staircase is designed with still greater delicacy, the white marble being inlaid with slabs of a pale warm grey. In the presence of work such as this it is only the young or inexperienced architect who will wish for more color and decided contrasts. Those who have any real sense of art will soon learn to appreciate at their true value these quiet harmonies and subtle combinations of tints. It is, however, only on a large scale that the Italian masters dreaded and avoided strong contrasts. In their smaller inlays and mosaic patterns they sought brilliancy and distinctness, and used the strongest contrasts, not only of color, but of light and dark. Strangely enough, it is in small work such as this that modern men seem to choose marbles that will not contrast, and arrange them so as to produce no decided effect. That disagreeable Irish green, of which I have spoken, is often used next to a piece of pale red, without that intervening white or black which would have prevented their running together, and the result is a confused piece of color that has none of the brilliancy that is essential to design in mosaic. The true masters of mosaic worked in a very different way. They chose strong positive colors, the dark red of porphyry, and the deep green of serpentine, if they could get them, and almost always separated them by white, or pale yellow. A beautiful effect is produced in the inclosure of the stalls at the Baptistry of Pisa by simply inlaying a dark green marble in the white marble of the inclosing wall, so as to form a pattern in dark green and white, of which the white is the actual material of the ground left between the dark inlaid pieces.* This kind of sharp, trenchant design is the descendant of the old Lombard inlaid work, such as that in the Duomo and San Michele at Lucca, and San Miniato at Florence, and it was continued in a later form in the incised work filled in with black marble or cement, of which there are examples in the doorways of the Palazzo Communale at Cremona, the screens at San Petronie at Bologna, and some fountains now in the South Kensington Museum. Here, again, should be noticed the very limited number of colors with which these mosaics or inlays are worked. In the glorious pavements of opus Alexandrinum which cover the floors and add so much to the beauty of the Roman basilicas, and innumerable other churches in Italy, and whose beauty is not less remarkable than their variety of pattern and design, there are seldom more than three kinds of marble used—red porphyry, green porphyry or serpentine, and white; the white, however, generalaly cut from a marble which has veins of other colors in it, so that the piece which, according to the pattern ought to be white, is sometimes yellowish or pinkish or grey instead, and a certain amount of variety is thereby obtained, which prevents the hardness of a perfectly regular mosaic. The patterns thus produced are inlaid in a plain white marble field, and with these simple materials effects are produced which are not only harmonious, but constantly novel, each pavement having its own distinguishing character, by which it can be distinctly remembered.*

I turn now to another rule for the employment of marble, which may not be generally accepted, but which seems to me of no less consequence than the rest. Marble differs from stone, not only by its superior hardness and by its qualities of color, but by its semitransparency and the polish which it takes. The combination of these qualities, but especially the last, makes it difficult to use marble and stone together in the same design. Carving in stone must be free, that in marble severe: design in stone must be well relieved, and expression must be given to it by architectural features; design in colored marbles must be plain and flat, and characterized by smooth surfaces of color; and on these grounds alone the two materials can scarcely be used safely together. But the contrast between the opaque granulated texture of stone and

* Several examples of inlaid work similar to this, in dark green and white, or with the addition of a dull red as a third color are illustrated in Waring's "Arts connected with Architecture in Central Italy." Plates 22 to 30.

* Several pavements of opus Alexandrinum are illustrated in Sir M. D. Wyatt's "Geometrical Mosaic of the Middle Ages" (*vide* plates 1 to 7). Restraint in number of colors may also be observed in the illustrations of decorative art in other materials in the same volume. See also Gruner's "Specimens of Ornamental Art."

the polished semitransparency of marble is so great, and the effect, when they are placed side by side, is so disagreeable, as to be intolerable to an educated eye. If the marble is not polished, the contrast is more endurable; but then, of course, the full beauty of the marble is not brought out, and it is no better than colored stone. It is less intolerable when marble is used for detached shafts, though even then it is a question whether simple stone would not have been better. The instance of the frequent use of Purbeck shafts in our English cathedrals is, I am aware, an authority that may be adduced against my rule; but I venture to think that even they are not always an improvement to the design; and it should be remembered that originally they did not stand as they now do,—stark and sharply-defined against white stone,—but were supported by colored decoration on wall and pier, which has now disappeared. But if the sober grey of Purbeck may be forgiven, what shall we say for the multitude of marble shafts of all colors and sizes that one sometimes sees in modern churches?—round the pulpit, perhaps, a dozen little colonettes, 2in. in diameter, and round the font half as many more, all of different kinds and colors, reminding one of nothing so much as the samples of polished drawing pencils in a colorman's window; and then, perhaps, on the piers or the jambs of the chancel arch, large shafts of Cornish serpentine that look nearly black and shine beautifully, all standing in hard cold relief against common stonework, and grating on the nerves by the disagreeable contrast between its dead surface and softened outlines and their glossy polish and hard positive forms? It is a safe rule that marble and stone should not be combined in the same design. If ever it is necessary to bring them near one another, let there be a strong definite line of separation, and let there be all marble on one side of it and all stone on the other; so shall we minimize the unpleasant effect which almost always arises from the combination of materials so different.

These, then, are a few of the lessons which are taught us by the nature of marble and the other materials which I have classed together with it, and by the practice of those who have every claim to be considered as our masters in the use of them. Let me briefly recapitulate them:

1. Decorative carving in marble, as, for instance, in cornices, capitals and friezes, where high relief and bold design are required, should be severe and conventional. Naturalism is forbidden by the stubbornness of the material except in the highest subjects, such as the human figure, which repays the necessary expense of labor, or else in very low reliefs when the labor of execution is reduced within moderate limits.

2. Sculpture should be in white marble, or, if in alabaster, only in such as is free from veins or stains of color.

3. Moulded architectural features, such as bases, bands, strings, cornices, architraves, abaci, should be either in white or in some uniform color without markings or veins.

4. Variegated marbles should be used only for panels or columns, or, in other words, on plain smooth surfaces, either flat or curved, so as to display the beauty of their markings to the utmost, without interfering with any of the structural lines of the architecture.

5. Colored marbles should be used in moderation, too great a variety being avoided, and those of the quieter and more harmonious tones preferred for general use.

6. Strong contrasts of color on a large scale are dangerous, and generally incline to vulgarity.

7. Strong contrasts on a small scale, as in mosaics and inlaid work, are necessary.

8. Stone and marble should be kept apart as much as possible.

In conclusion, it will be useful to consider how far, with these principles to work upon, marble is suitable to our English architecture. Most of the rules which I have just recapitulated, and which are derived from observation of the material itself, and the modes of using it which have been suggested and taught by its natural qualities, seem to point rather to Classic than to Gothic design. Severe conventional foliage, restraint imposed on freedom of representing natural forms, large plain wall-surfaces, and large columns, all seem to belong to Classic architecture rather than to our native Northern styles, which de-

light in naturalism, break up the wall surfaces with variety of architectural features, and compose their piers of small clustered shafts in preference to single columns, being in everything the very opposite of the mode of design which marble seems to require. And, indeed, I have no doubt, as I have already implied, that the qualities of marble have had as much to do with forming the character of Classic architecture, as those of stone with that of Gothic architecture. The very forms of Classic mouldings, with their square reveals and absence of undercutting, seem derived from the difficulty of working marble into hollows, and the necessity of right-angled sections, to throw distinct shadows in a partially translucent and strongly reflecting material. But it does not follow from this that, unless we give up Gothic architecture, we must give up the use of marble; nor even that we must give up our Northern Gothic and adopt that of Italy, which is in many respects a marble style. Our native Gothic is the result of our native climate, and our own natural character; and I for one believe firmly that no style will ever firmly root itself among us which is not at bottom based on the art which sprang up among us spontaneously, and which in country districts retained an obscure lingering existence all through the reign of pure Classicism and down to our own days. But our architecture may still remain true to Gothic principles in spite of our adoption of materials and conditions for using them that are new to the Gothic of the past. For instance, the art of the Early Renaissance among us is much more a Gothic than a Classic art. The mansions of Kirby, Hardwick and Burleigh, in England, and those of Chambord and Blois, in France, have nothing in common with Whitehall or Versailles. They are in principle Gothic buildings, in spite of the features and ornaments they have borrowed and adapted from Classical architecture. It was not until the Gothic element in the Jacobean style dropped out, and the temptation to indulge in the glories of pure Classic architecture triumphed, that we ceased to have a native style of our own; and we lost it then not because we carved acanthus leaves in our capitals, and made our shafts to taper, and copied the sections of Classic mouldings, but because we adopted the principles of Classic construction. Now we too, like our forefathers in the 16th century, have a choice of styles before us. Eclecticism is forced upon us. Unless we work like pedants we cannot help being influenced by other styles than Gothic, even if we make that the basis of our work. We must be bigots, indeed, if we refuse a noble and beautiful material because we find the rules for employing it to advantage are different from those that are proper to the stone we have been accustomed to. We should rather, as I said before, welcome it as an opportunity for a fresh departure, as a lever for lifting our modern work out of the groove of mere imitation of one style among the many from which we have to learn our lesson. On our architecture externally the adoption of marble can have little effect. Our climate forbids its use. Even in Italy the conglomorate marbles and breccias become disintegrated by exposure to the weather, and in England it would be folly to use them out of doors. White statuary is with us scarcely more durable, and though that harder kind of Carrara which for some mysterious reason we are in the habit of calling Sicilian is more durable, it soon loses in the external air all the appearance of marble, and looks little, if at all, better than any other white stone. Colored marbles, too, are of little use to us for external decoration, for their polish soon disappears, and with it their peculiar beauty, and they soon become less effective than many ordinary stones that are available for the same purpose, such as the red magnesian limestone of Mansfield, the grey Forest of Dean, the red sandstones of Bristol and other places, and the purple sandstones of St. David's, all of which have the advantage over marble of durability under exposure to an English climate. But in the interior of our buildings there is ample opportunity for the use of marble. It is, indeed, the only stone which is tolerable in positions where we must touch or brush against it. The passion of the earlier Gothic revival for showing honest building material within doors has fortunately run itself out; it was never warranted by the usage of the original style, and it was

found practically inconvenient. Our stone chimney pieces came off white on our clothes, grew smokey, and could only be cleaned by rubbing or scraping away the material; our stone fenders became dirty, and people wore them away by putting their feet upon them. And in more important architectural features it was found more comfortable to come into contact with wood and plaster than with bare stone. To marble, however, none of these objections apply. It is perfectly cleanly, and so hard that wear has little effect upon it within doors; and though in private dwellings its costliness must prevent any very large use of it, it need not exclude it altogether, while in public buildings nothing can be more appropriate or beautiful than marble for door cases, isolated piers or pillars, staircases, balustrades, pavements, and in more important buildings linings of wall surfaces, and even the structural members of the architecture itself. Of its suitability to church architecture there is no need for me to speak, for one seldom enters a modern church without finding marble used somewhere, though not always with good taste and judgment, nor in the right place. My subject has, perhaps, novelty to recommend it to your notice; for, largely as marble is now employed, there has, so far as I know, been but little attempt made to reduce the method of using it to any definite principles. We have rather dropped into the practice of employing it as we think best, without any general rules to guide us, and, consequently, we often employ it very absurdly and irrationally. It is time we began to consider the matter more scientifically, to apply to this new material those general principles of common sense and utility by which we admit all good art is governed, and thereby to arrive at some general rules by obeying which we may avoid mistakes for the future.

HYDRAULIC EXPERIMENTS AT ROORKEE.*

The report of the experiments of Capt. Cunningham, recently published, form an important addition to the literature of hydraulic engineering, continued through a period of nearly four years, under exceptionally favorable circumstances, and, prompted by a desire to contribute to our present knowledge of this department of practical engineering. These experiments possess a value not easily estimated.

The design of the work was conceived by the author while he was Assistant Principal in the Thomason C. E. College at Roorkee. It appeared to him that the neighborhood of the great Ganges Canal presented an unusually favorable opportunity for experiment, provided the proper superintendence could be secured. He accordingly proposed to Government a scheme for such work and volunteered the personal superintendence.

The Ganges Canal, the site of these experiments, is the largest canal in Northern India. It is 350 miles from its head at Hardwar to its outfall at Cawnpore. In its upper portion it is about 190 feet wide and 10 feet deep, discharging about 7,000 cubic feet of water per second at full supply; it decreases gradually in breadth and depth as it parts with its water for irrigation purposes. These irrigation channels, technically called Distributaries, of 20 feet in width, as well as the so-called Branches of 70 feet, are of themselves fair-sized canals.

The site selected for a large portion of the systematic work was that section of the canal extending across the valley of Solani River, a distance of $2\frac{3}{4}$ miles. The canal is here carried along the so-called Solani embankment; an earthwork having a width of 242 feet at the top and 317 feet at the base. For a length of $1\frac{1}{4}$ miles in one place and $\frac{1}{2}$ mile in another, the cross section of the embankment is quite uniform. Each side of the canal bed here consists of 12 masonry steps plastered with fine plaster, the lowest step having a rise of four feet, and each of the remaining eleven a rise of nine

* Roorkee Hydraulic Experiments, by Capt. Allan Cunningham, R. E. Honorary Fellow of King's College, London. Roorkee: Published at Thomason College Press.

inches, and all having a tread of fourteen inches. The width between the lowest steps is 150 feet.

Over the Solani River the canal is carried by a fine masonry aqueduct bridge of 15 arches of 50 feet span and a width of 192 feet. The aqueduct is here divided into equal waterways, each of 85 feet width and 932 feet long. The cross section of either aqueduct is a rectangle of 85 feet width. The surface exposed to the water is fine plaster laid over the brickwork.

Most of the experiments were made in the right-hand one of the twin aqueducts.

The primary objects of the work were: 1st. The discovery of a good method of discharge measurement. 2d. Testing the applicability of known mean-velocity formulas. 3d. Discovery of a good approximation to mean velocity for large canals.

The experiments were specifically directed towards the determination of the following data, viz.:

The velocity.
Unsteadiness of motion.
Surface slope and convexity.
Vertical velocity curves.
The proper function of rods.
Transverse velocity curves.
Mean velocity.
Discharge verification.
Silting.
Evaporation.

The results throughout have been compared with those estimated from the obtained data by the use of the several well-known formulas.

Of the four years work pursued under all the conditions afforded by the locality, and with all the various methods and instruments usually employed for the purpose, the author presents the following summary:

SUMMARY—INTRODUCTION.

Existing modes of discharge-measurement of large bodies of water are of doubtful accuracy.

New experiment is wanted on large bodies of water in motion under simple conditions, as in large regular canals.

A site to be very favorable for experiment should be situated in a straight uniform reach of great length, that is, with uniform banks, uniform bed, and uniform bed slope for a great distance above and below; and to be suitable at all for experiment must not be situated in a marked hollow in the bed slope.

VELOCITY MEASUREMENT.

Velocity in hydraulics usually means *forward* velocity, or the resolved part of the actual velocity taken parallel to the current axis.

Mean velocity measurements of all kinds are not sensibly affected by errors in estimating depth or breadth, but only by errors in the primary velocity measurements on which they depend.

In using floats, neither obliquity nor crookedness of path necessarily interferes with their proper use.

Floats measure the average of the forward velocities of the fluid particles successively displaced along the float path.

Floats can be used with advantage only at a favorable site, and not near irregular, nor very close to, any banks, however regular.

Floats have many advantages over *fixed* instruments, viz.: they interfere little with the natural motion of the water; they measure velocity directly; can be used in streams of any size; are little affected by silt or weeds; measure forward velocity; can be made and repaired by common workmen, and are cheap.

The ropes defining the run must be stretched at the lowest possible level.

A moderate deviation from the float course is admissible. This deviation being greatest in mid channel, decreasing slowly towards the banks, and rapidly close to the banks.

Strict accuracy in the position of the pendants is not essential.

To save time the dead-run must be reduced to a minimum near the banks, especially with surface floats.

Sub-surface floats require increased length of dead run as the depth of submergence increases.

For accurate timing the eye should be free to watch the visible phenomena, while the timing should be wholly done by the ear.

Similar observations at the beginning and end of the timing should be done by the same observer, so as to eliminate personal equation.

Precision in timing admits of short

runs which both save time and conduce to accuracy of course.

Long runs waste time. The run should be the shortest compatible with good timing.

With really good timing a 50-foot run is a good standard for general use; smaller ones must be used near the banks.

No float which is not a good float should be recorded. The sole criteria of a good float (the float's passage) being that it runs free and in fair course.

DETAILS.

The mean of highest and lowest free-water levels within a short interval, may be accepted as the average free-water level at the time.

This free-water level is slightly higher than the still-water level. For great accuracy, such as slope measurement, the free-water level should be taken. For ordinary work either the free or still-water level may be used; the same one to be used constantly at the same spot.

The average free-water level on either bank may be accepted as that of the site, except in case of high cross wind; then the mean of results on both banks may be taken.

The mean of the initial and final water level of an experiment may be accepted as the mean water level of an experiment.

In rough beds average cross sections should be determined from the average of several soundings along the course, and average depths determined from these should alone be used in computation.

The determination of average depths depends ultimately on the water level determination, so that the depths are liable to an error of a few hundredths of a foot, if the water level be taken from one bank only in a high cross wind, and this error would effect all computed results in which the depth entered as a factor.

Soundings should be taken whenever possible, with sounding rod from a boat floating freely down stream.

UNSTEADY MOTION.

The velocity at any one point of water is very variable, both in magnitude and direction, and the variation is very rapid; that is the motion is essentially *unsteady*.

Single velocity measurements are of very little practical use. Average velocities are the only results of much practical use.

Hydraulic experiments on large bodies of water must necessarily be both tedious and expensive, from the tediousness of determining average velocities.

Unsteady motion necessitates the use of a large stock of floats.

When velocity measurements at numerous points are required, the external conditions will probably change in the time required for obtaining so many average values. To meet this difficulty, the work should be done in *sets* of a few velocity measurements only, and should be done as rapidly as possible at each point in turn.

The details of each set will be under nearly the same external conditions, and the average results of many such sets, under nearly the same average external conditions.

The mean of about fifty velocity measurements, done in rapid succession, may be accepted as an average velocity measurements.

Only such sets as are under tolerably similar external conditions, should be combined into series. The combination should be so as to eliminate personal equation.

The average velocity curves for sites of regular contour in a long uniform straight reach are pretty regular curves, generally convex down stream. The departures from regularity in actual diagrams, are probably due to insufficient number of measurements, and to irregularity of contour of bed and banks at or near the site.

Discharge measurements or velocity measurements taken from single sets, are only fair average values.

The stream lines of water in motion interlace freely in all directions. There is an average steady motion. The unsteady motion is analogous to that of the wind.

The property of unsteady motion enormously increases the difficulty of forming a rational theory of fluid motion.

SURFACE SLOPE.

Surface slope measurement is an extremely delicate operation.

The slope length should be the shortest, yielding a surface fall greatly exceeding the ordinary oscillations of the free level.

The water level at the two slope points should be taken simultaneously. The points should be equidistant from the center section of the experimental site, in positions free from eddies and back waters, where the motion of the water is as quiet as possible, and with nearly equal surface velocities past them; the channel also should be symmetrical, both geometrically and physically, about the site throughout the slope length, and for some distance above and below.

Different slope lengths give different results, so that it is impossible, probably, to obtain true local surface-slope measurements. The same slope length should be used at any one site.

The surface slope of opposite banks are generally unequal. Local surface slopes should be deduced from simultaneous measurements on both banks.

The local surface slope does not change in any obviously regular manner with change of depth. It partakes of the changes of the surface falls of the upper and lower sub-reaches. It decreases rapidly with increase of obstruction at tail.

At times of high-water level, with no temporary obstruction at tail, the free surface sinks as follows. In nearly parallel lines in the upper sub-reach; in converging lines (with gradually flattening gradient) in the lower sub-reach; obstruction at the tail flattens the free surface gradient for a long distance back; with greatest effect in the region below the level of the crest of the obstruction, and with rapidly decreasing effect beyond this.

The surface gradient is chiefly determined by the control (chiefly obstruction) at the tail.

SURFACE CONVEXITY.

The measurement of convexity or concavity across the free surface is an exceedingly delicate operation.

The water surface in a long straight reach, with pretty straight banks, is, on the average, nearly level across.

SUB-SURFACE VELOCITY INSTRUMENTS.

Twin floats do not, in consequence of the unsteady motion, give a proper value of the velocity in the path of the sub-float.

The most serious fault of the double float is the rapid increase of connector resistance with increased depth of the sub-float. Other faults can be removed by suitably proportioning the parts of the instrument.

The efficiency of a given double float decreases with increase of depth of the sub-float, and there is a limit of depth beyond which it fails. To secure equal efficiency at all depths, the sub-float should be increased in size and net weight as the depth increases.

The sub-surface velocity measurement, made with the double float, is attributed to a depth always greater than the real depth of the sub-float, and is always more or less affected by the surface float and connector resistances.

VERTICAL VELOCITY CURVES.

Frequent re-adjustment of the connectors of double floats is inconvenient. Sub-surface velocity measurements, with double floats, can therefore only be done with convenience at fixed depths.

The properties of the average vertical velocity curves are as follows: The curves are generally convex down stream (except near an irregular bank); the maximum velocity is usually below the surface; the maximum velocity sinks in a rectangular channel from the center towards the banks, and is about mid-depth near the banks; the velocities near the bed are generally the least; the mid-depth velocities are generally greater than the mean; the curves are decidedly flat; the flatness decreases in a rectangular channel from the center towards the banks.

Vertical velocity curves obtained with the double float are distorted by instrumental defects as follows:

1*st*, *Max. Velocity at Surface.*—The partial errors are cumulative; the observation curve lies wholly without the true curve, and the error increases with the depth.

2*nd*, *Max. Velocity below Surface.*—From the surface to the maximum velocity line, the partial errors are cumulative;

from the maximum velocity line to a point where the velocity is equal to the surface velocity they are partly compensatory; below this line they are again cumulative. From the surface downwards the observation curve lies within the true curve, crossing it at a point somewhere in the second region above named; below this point it lies wholly without the true curve and the error increases with the depth.

The observation curves obtained with the double float are all too flat, especially near the bed, where the velocities are all exaggerated.

The mid-depth velocity on any vertical is subject to great and rapid variations from instant to instant, but to a less extent than the surface and bed velocities.

The bed velocity is subject to much irregularity.

Any marked change of any one velocity is accompanied, on the whole, by a *similar change* of all the velocities past the same vertical.

VERTICAL VELOCITY-CURVE FIGURE.

The investigation of the figure of the vertical velocity curve is a very delicate inquiry, as the data available (velocity measurements) are not good data for the purpose.

The method of trial and error is altogether unsatisfactory for the purpose, if the depth of maximum velocity line and parameter of the curve are to be discussed. The method of least squares is alone satisfactory in such case.

The average vertical velocity curve approximates in general closely to a parabola with a horizontal axis.

The data do not admit of the determination of the depth of maximum velocity line and parameter of the curve (which define the position and size of the curve) with any closeness.

The maximum velocity line is usually above the mid-depth on all verticals, and above one-third the depth on verticals at or near mid channel.

The tracing of the dependence of the maximum velocity depth and the parameter of the velocity parabola, on external condition, is very uncertain.

The Mississippi and Bazin experiments formulæ, for the parameter, are not based on good evidence.

DEPRESSION OF MAXIMUM VELOCITY.

The position of the line of maximum velocity on any vertical does not depend sensibly on the depth of the water, nor yet on the state of the wind. Wind must be long continued to sensibly affect the position of the maximum velocity line.

The air surface is a part of the wet border, causing a slight but sensible resistance to flow. The depression of the maximum velocity line is due largely to the air resistance.

DISCHARGE PAST A VERTICAL.

The arithmetic mean and trapezoidal rules for areas both err in defect on the whole.

The discharge past a vertical, found by use of a double float, is greater than the true discharge when the maximum velocity line is near the surface, and approaches equality with it as that line sinks to about one-third the full depth. As this line sinks further the discharge measurement falls short of the true discharge, and the discrepancy increases as that line sinks.

MEAN VELOCITY PAST A VERTICAL.

The arithmetic mean of velocities past a vertical is less than the mean velocity.

The mean velocity past a vertical varies less than most of the velocities of which it is the mean, but it is by no means constant.

The mean velocity measurement exceeds or falls short of the true mean velocity, according as it is less or greater than the surface velocity.

For finding mean velocity past a vertical by velocity measurements *at more than one point*, the formula, mean vel. $= \frac{1}{4}(V_0 + 3V_{\frac{2}{3}H})$ combines accuracy with the greatest practical convenience. (In this formula V_0 is the surface velocity, and $V_{\frac{2}{3}H}$ is the velocity at two-thirds the depth.)

The mean velocity is always below the mid depth.

The mean velocity past a vertical can only be approximated to by velocity measurements at a single point.

The average mid-depth velocity is generally greater than the mean of its vertical.

The ratio of mean to mid-depth ve-

city is not constant, but liable to about 16 per cent. variation.

The mean velocity past a central vertical increases and decreases on the whole, with increase and decrease of either depth or surface gradient.

The relation of the mean velocity to the external conditions is too complex to be worth endeavoring to trace out by mere experiment; that is, without some guide from a rational theory.

A much closer approximation to the central mean velocity may be obtained by direct velocity measurement of any one primary velocity past center vertical, than from any known formula in terms of surface gradient.

The best practical mode of mean velocity measurement in depths over 15 feet is to attempt only approximation by velocity measurements at $\frac{5}{8}$ depth, as a general rule, or $\frac{1}{10}$ depth close to vertical banks.

RODS.

The full length of a rod should only slightly exceed its immersed length. A long rod is quite unfit for use with small immersion.

Top hooks are a useless addition to a rod.

The rod-velocity of a rod nearly grazing the bed gives an approximation to the mean velocity past the vertical, generally closer than that given by the double float.

Rods move more steadily than any other sort of float.

The advantages of rods are, as compared with the double float, as follows:

They are free from the uncertainty attending the instability and unknown lift of the double float. They give an approximation to mean velocity past a vertical usually closer than that given by the double float. They give the result more rapidly. They are more easily handled and less delicate. They are simpler in construction, cheaper and more durable.

For measurement of mean velocity past a vertical, the rod should supersede all other instruments in cases favorable to their use.

The conditions favorable to the use of rods are: A reach of nearly uniform cross section and average bed scope throughout great length. The bed should be tolerably even length ways at and near the site. The depth should not exceed about 15 feet at and near the site.

The site should be prepared for the use of rods, as follows: The bed should be dressed to a tolerably uniform cross section and longitudinal slope for a length of, say, 250 feet. The banks should be dressed to a tolerably uniform slope for a length of, say, 250 feet, and, if likely to suffer erosion, should be revetted with masonry.

THEORY OF ROD MOTION.

The rod velocity is, within the limits of practice, always somewhat more deeply seated than the line of mean velocity past its immersed length, and is, therefore, within the limits of practice, always *somewhat less* than the mean velocity past its immersed length. For mere accuracy of measurement of mean velocity past a vertical, the immersed length of a rod should be *decidedly less* than the full depth on the vertical.

The proper immersed length of rod is from .950 to .927, or an average .94 of the full depth of the water.

TRANSVERSE VELOCITY CURVES.

For tracing the figure of the transverse velocity curves, the float course spacing in a canal should be: Symmetric about mid-channel; wide spaced over the level part of the bed; closer spaced with approach to the banks, and with one float course at the foot of each bank; closest spaced nearest the edge.

If discharge measurement is the aim in view, there should be a primary division into spaces as above, and these should be subdivided into a number of subspaces which should be multiples of 2, 3 or 6.

The properties of the average transverse velocity curves are as follows:

I. The velocity variation (in any one curve) approximates to the following distribution (in the case of a symmetric cross section with a level or wholly concave bed in a uniform long straight reach): the maximum velocity near the center; a very slow decrease of velocity from the center towards both banks, which becomes more rapid with approach to the banks, and is very rapid close to the banks; the curve is wholly convex

down stream, and is symmetric about mid channel.

II. Every marked change in the figure of the bed produces in general a marked effect on the figure of the velocity curve as follows: Increase of depth tends to increase of velocity, and *vice versa ;* the maximum velocity line tends to be in the deepest channel (if sufficiently far removed from the banks) ; a convexity in the bed causes a concavity in the velocity curve, and *vice versa ;* these effects are more marked in shallow than in deep water.

III. Velocity at same point in like curves increases and decreases *cœteris paribus* with rise and fall of water level.

IV. Like curves are similar under similar external conditions.

V. Like curves of equal mean velocity are *cœteris paribus* equally flat as a whole.

VI. Curves of low velocity are *cœteris paribus* flatter than those of like kind of high velocity.

VII. The flatness of a curve does not depend so much on the general depth of water as on the mean velocity, so that curves at low water are not necessarily flatter than curves of like kind at high water.

VIII. These curves are sharply rounded over sloping or stepped banks, and more fully rounded near vertical banks.

IX. At sites of similar character like curves are, each taken as a whole, flatter throughout at the wider sites.

X. Of unlike curves under similar external conditions in the same rectangular channel, the mid-depth curve is usually the outer (except near the center), the mean velocity curve intermediate, and the bed curve the inner.

Also, the mean velocity curve is one of the flattest and the surface curve is the most fully rounded.

The forward velocity near the edge decreases rapidly with approach to the edge.

At the edge the forward surface velocity is very small, perhaps zero. Near the edge there is a persistent flow, at and near the surface, from the edge toward the center, most intense nearest the edge, and decreasing rapidly with distance from the edge.

TRANSVERSE CURVES—GEOMETRIC FIGURE.

The investigation of the figure of the transverse velocity curve is a very delicate inquiry as the data available (velocity measurements) are not well suited to the purpose.

In curves of like kind, with same water level at same site, the velocities at same points are nearly proportional, so that such curves are approximately parallel projections of one another.

The transverse curves resemble semi-ellipses in general shape, but with flatness increasing as the water level sinks, in such a way that the exponent (of the order of ellipse) increases as the water level sinks.

The wet border (including the air in this term) is the ultimate source of retardation of flow.

Velocity at any point is probably a function of the average effective distance from the wet border.

AREAS AND DISCHARGES.

The number of repetitions of any observation measurement should be proportional to its "weight" in the computation formulæ.

The trapezoidal and arithmetic mean rules err in defect in the long run, and when the bed is concave, the error is not necessarily very small.

The chief advantage of the process of discharge measurement used in this work is the completion of the field work of a single result within a moderate time, within which the external conditions (except wind) may be presumed to have been tolerably constant.

The cubic discharge increases and decreases rapidly with rise and fall of water level, but depends to at least an equal extent on velocity.

The cubic discharge is sensibly constant from instant to instant.

A cross wind is liable to cause excess or defect, according as it blows to or from the gauge.

The chief source of the variability of cubic discharge measurements (under apparently the same external conditions) is that, in consequence of the unsteady motion each single result is an imperfect one.

Discharge tables should be tables of double entry, showing both gauge-reading and surface slope or gradient as argument.

MEAN VELOCITY.

The arithmetic mean of velocities errs in defect.

The mean velocity past a transversal and the mean sectional velocity are less variable from instant to instant than most of the individual velocities.

The mean velocity past a transversal varies sensibly from instant to instant.

The mean sectional velocity is constant from instant to instant, and in a higher degree than the cubic discharge.

The chief source of variability of mean velocity measurements (under apparently similar external conditions) is that, in consequence of the unsteady motion each single result is an imperfect one.

There is a general sort of agreement in the variation of the mean surface and central surface velocities, and also in that of the mean sectional, central mean and central surface velocities; also of the quantity $\sqrt{RS}$ with the latter three (R being hydraulic mean depth, and S= local surface slope).

The mean surface and central surface velocities, and also the mean sectional, central mean and central surface velocities, and the quantity $\sqrt{RS}$ increase and decrease with increase and decrease of either hydraulic mean depth or surface gradient.

Surface velocity measurements, and therefore also discharge measurements depending on them, are liable to be under or over estimated in high or up-stream or down-stream wind.

The mean velocity measurement is only slightly, if at all, affected by up and down stream wind. Surface velocity measurements made in high up or down stream wind are quite unsuitable data for discharge computation.

The mean velocity measurement is not sensibly affected by a high cross wind, but is *attributed* to an abnormal gauge reading.

The ratio $c=V\div U_o$ increases in general with increase of depth and probably also with decrease of velocity or surface slope. (V=mean sectional velocity, U_o= mean surface velocity.)

The variation of the ratio between mean sectional velocity and central surface velocity is very obscure, probably in consequence of the disturbing effect of the wind on the surface velocity.

The ratio $V\div 100\sqrt{RS}$ increases and decreases generally with increase and decrease of hydraulic mean depth; depends also in some complex manner on the surface slope, and also on the nature of the banks and bed.

The form of the Bazin co-efficient

$$C=\left(\alpha+\frac{\beta}{R}\right)^{-\frac{1}{2}} \text{ is defective.*}$$

The mean velocity and cubic discharge measurements obtained by applying Bazin's co-efficient for reducing central surface velocity measurements to mean velocity are generally *under estimated.* The deficiency is so great that this co-efficient is of little practical use in earthen channels.

Bazin's relation (expressing ratio of mean sectional velocity to maximum velocity), $c=100C\div 100C+25.34$ is fundamentally incorrect as a relation between mean sectional velocity, central surface velocity and C.

Kutter's co-efficient is one of pretty general applicability. When the surface slope measurement is a good average, it gives results whose error will probably seldom exceed $7\frac{1}{2}$ per cent. in large canals.

The Mississippi Experiments Formula is useless as a *general expression* for mean velocity (except, perhaps, in cases of very low surface slope).

Further experimental research for an improved mean velocity formula is an almost hopeless task until the *proper* functional form is suggested by an improved rational theory.

A close approximation to mean velocity is more likely to be obtained by formulas depending on velocity measurement than on surface slope measurement.

Central mean is to be preferred to central surface velocity measurement for use in approximating to mean velocity.

The connection between mean velocity and any other primary velocity is of a more intimate and simple kind than between mean velocity and surface slope; the former being probably a more geometrical, while the latter is a physical relation.

For rapid approximation to mean velocity a *good* average central mean velocity measurement is (at present) the most reliable.

DISCHARGE VERIFICATION.

For comparison of successive discharge

* C is the ratio $V\div 100\sqrt{RS}$; α and β are quantities supposed to depend chiefly on the state of the bed, and, to a small extent only, on the slope. Bazin gave values to α varying from .457 to .853, and to β from .405 to 3.5.

measurements *at the same site*, such as are done in immediate succession, are much the most suitable.

For comparison of the cubic discharges *through successive sites*, the field work should be either *simultaneous* or else *in same* body of water at all the sites.

Under favorable circumstances the process of cubic discharge measurement used on this work yields consistent results.

The discordance between successive comparable results may be expected to be seldom over 3 per cent. (when the conditions are nearly similar and the circumstances favorable.)

CURRENT METER WORK.

By use of a proper current meter-lift the following advantages are secured, viz.: Certainty of orientation and position; of gearing and ungearing the current meter; also measurement of forward velocity (besides some minor advantages).

By separation of the recording works and connecting them electrically with the fan, the following advantages are secured; reduction of disturbance of the water; certainty of gearing and ungearing; increased delicacy; saving of delay of lifting to road, and vision of the motion of an index copying the movement of the fan. The uncertainties attending these instruments, as at present made, are very great.

SILT.

There is no obvious connection between the velocity and silt-density *at different parts* of a site. The silt-density varies from instant to instant at one and the same point.

The silt density and silt discharge do not appear to depend sensibly on either the depth or velocity at a site.

The silt density and silt discharge in the Ganges Canal depend chiefly on the quantity of silt present in the supply admitted into the canal.

EVAPORATION.

The evaporation from (an evapometer floating on) a large still-water surface or on a river is much less than from a small vessel on dry land (from the liability of the latter to become superheated).

The evaporation from the Ganges Canal, near Roorkee averages about $\frac{1}{10}$ of an inch daily (out of the rainy season).

The evaporation loss is about $\frac{1}{150}$ part of the full supply of the canal (or about 10 minutes full supply daily.)

The foregoing summary is the briefest possible compend of the author's conclusions drawn from the work, the account of the details of which fills, including tables and plates, three royal octavo volumes.

EXPERIMENTS ON THE FLOW OF AIR THROUGH ORIFICES IN A THIN PLATE.

BY A. FLIEGNER.

From "Civilingenieur" for Abstracts of the Institution of Civil Engineers.

THIS is a supplement to the author's previous article on "The Flow of Air through well-rounded Orifices."* He has determined experimentally for six orifices of different size, *i.e.*, 3.17, 3.87, 5.11, 6.62, 8.68, and 11.36 millimeters diameter, the weight of air flowing through the same at various pressures, both inside and outside the air vessel. The orifices used were made in brass plates 12 millimeters (0.47 inch) in thickness, drilled cylindrically for about $\frac{1}{2}$ millimeter, and then conically enlarged towards the outside at an angle of 45°. The results of the author's observations are given in a tabular form. From these experiments he has, with the help of formulæ already given in his former article—and various assumptions the sufficiency of which he considers to be attested by the results — developed several new formulæ for the purpose of calculating with greater accuracy than with those hitherto employed, the weight of air flowing per unit of time through an orifice in a thin plate.

* *Vide* Minutes of Proceedings Inst. C. E., vol. liii, p. 295.

The author adopts in the first instance the formula

$$G = aFp_m\sqrt{\frac{2g}{RT_m}\left(\frac{k+\nu}{k+1}\right)\psi} \quad . \; . \; (4)$$

where $\psi = \left(\frac{p}{p_m}\right)^{\frac{2}{n}} - \left(\frac{p}{p_m}\right)^{\frac{n+1}{n}}$ . . . (3)

p being the pressure in the most contracted section of the out-flowing air jet, a the co-efficient of contraction, while the other letters have the same signification as in the previous article.

The influence of heat imparted from outside is neglected as being very small, in consequence of which $\nu = o$, while it is assumed that the internal resistance offered to the outflow of the air as far as the section of greatest contraction is the same as for a well-rounded orifice; with the help of these suppositions the limits between which lies the value of the exponent n may be determined; they are 1.37 and 1.41. The principal object of the author's investigations is to determine the value of a; this he finds to be variable, depending on the diameter of the orifice, and in a greater degree on the ratio of the external pressure to the internal ($p_o : p_m$); these conclusions are arrived at by substituting the experimental values of the various quantities in the formula

$$a = \frac{G}{Fp_m}\sqrt{\frac{k+1}{k}\,\frac{RT_m}{2g\psi}} \quad . \; . \; . \; . \; (7)$$

which latter follows from the necessary modification and transformation of the formula (4) above stated.

The particles of fluid flowing from the orifice to the section of greatest contraction converge towards the axis of the jet, and in so doing follow certain curves. Assuming the orifice to be circular, the author supposes a section of the jet made in a plane passing through its axis, and in this plane the trajectory (a curve intersecting each of the curves followed by the different particles in the plane at right angles) to be constructed, from one end of the diameter D of the orifice to the other. In consequence of their convergent direction the particles of fluid in a section through the jet, made on the surface formed by the rotation of the trajectory round the axis of the jet, have a component of velocity at right angles to that axis, and therefore a certain amount of *vis viva* in that direction; at the section of greatest contraction this has disappeared, having been spent in work, that is, transformed into pressure. By formulating this relationship between the *vis viva* in a given section, and the work done in the contraction of the jet, the author arrives at a form of expression for a; in order to do this he has assumed the trajectory to be a cycloid. Although this is subsequently shown not to be the correct form, the results obtained would have remained unaltered had another curve been assumed.

After further investigation as to the influence of the pressures on the coefficient of contraction a, the author develops the following formulæ:

for $n = 1.37$

$$a = (1 - 2.8860\,D)\left(0.7880 + 0.1390\cos\frac{p_o}{p_m}\pi\right) \quad . \; . \; . \; (20)$$

for $n = 1.41$

$$a = (1 - 2.8860\,D)\left(0.7522 + 0.1318\cos\frac{p_o}{p_m}\pi\right) \quad . \; . \; . \; (21)$$

With the aid of these formulæ and those expressing the relationship between $\frac{p}{p_m}$ and $\frac{p_o}{p_m}$, which are:

for $n = 1.37$

$$\frac{p}{p_m} = 0.2820 + 0.4891\frac{p_o}{p_m} + \sqrt{0.0632 - 0.2374\frac{p_o}{p_m} + 0.2266\left(\frac{p_o}{p_m}\right)^2} \quad (18)$$

for $n = 1.41$

$$\frac{p}{p_m} = 0.2716 + 0.4962\frac{p_o}{p_m} + \sqrt{0.0650 - 0.2435\frac{p_o}{p_m} + 0.2333\left(\frac{p_o}{p_m}\right)^2} \quad (19)$$

the weight of air G flowing through the orifice in a second may be calculated from the formula (4) previously given (ν being o).

As the calculations involved in the expression just stated are rather complex, the author gives for practical purposes a more convenient formula (arrived at by purely empirical methods) for the weight of air flowing through an orifice, of the kind under investigation, in one second:

$$G_o = (3465 - 10000\,D)F\sqrt{\frac{p_m^2 - p_o^2}{T_m}} \quad . \; (24)$$

the weight G_o being in kilogrammes, the pressures expressed in atmospheres of 10,000 kilogrammes per square meter, and the dimensions in meters.

This formula may be used for orifices varying in diameter from 3 to 12 millimeters (0.11 to 0.47 inch).

In the tabular statement of results to which reference has already been made, the ratio of the values calculated by the above formula to the corresponding ones obtained by experiment are given, showing a close agreement.

THE STORAGE OF ELECTRICAL ENERGY.

From "The Engineer."

A GREAT deal has been written lately concerning the storage of electricity by means of Faure's secondary battery. That M. Faure had succeeded in improving upon the Planté pile has been known for some time in scientific circles, but no undue importance was attached to the fact. Of late, however, most extraordinary stories have been set on foot; and the columns of the daily press have announced that steam is in a fair way to be superseded; that the day of gas lighting is all but over, and that the ship of the immediate future will be propelled by electricity. We have contented ourselves up to this moment with an announcement of the nature of M. Faure's invention, and we have refrained from doing more lest we should inadvertently lend the invention a notoriety it does not deserve. M. Faure's patents have been bought in France, and there is good reason to believe that a company to work them has already been formed there, and that an attempt to form a similar company in this country will soon be made. The most exaggerated claims have been put forward for the invention—claims so exaggerated that there was reason to think that no one would be foolish enough to believe them. Unfortunately, however, Sir William Thomson unwittingly wrote a letter to the *Times*, which appeared on the 9th inst., and which might easily be used with great effect by the promoters of a company. Sir William Thomson told the world that he had carried a million foot-pounds with him stored in a space of one cubic foot. This sounds very large, and the daily press in certain cases became more enthusiastic than ever. But large as "a million foot-pounds" sounds, it is really very little, and Sir W. Thomson has, we feel certain, been misunderstood, and his incautious words have been made to imply what he never meant them to convey. Before going further we may explain that the force stored up in Sir W. Thomson's "box of electricity" would not drive a 1-horse power dynamo machine for more than half an hour, even if all the energy it represented could be made available in producing mechanical work. We may further explain that as a matter of fact there is no electricity whatever stored up in the box, which contains neither more nor less than a powerful galvanic battery, the duration of whose action is short.

As the claims of the Faure battery to notice as a money-making invention are being freely discussed, we propose to explain what it is in popular language—language which will not, perhaps, please the electrician, but will, nevertheless, convey to the reader who knows little or nothing of electricity a good idea of the action of this wonderful box, about which so much is being said. Probably all our readers know that if a plate of zinc and a plate of copper be immersed in a weak acid solution, and kept from touching each other, little or no action will take place. If, however, a wire be used to connect the two plates, what is called galvanic action takes place. A current of electricity passes through the wire, and the zinc becomes rapidly oxidized. After a time the zinc will all be oxidized, save a small portion inside, which is protected by the oxide from contact with the acid. When this happens, the action of the battery ceases. Now let it be supposed that a powerful current of electricity from another battery is driven in an opposite direction through the first-mentioned battery; the effect would

be to undo what had been done, the zinc would be deoxidized and ready for work again, and if metallic contact were prevented, the battery might be kept ready for action for a considerable period. In practice the result we have indicated cannot be secured with zinc and copper, for reasons which we need not stop to explain. We have stated that it would, because the statement conveys a clear idea of what takes place in the Faure battery; for although deoxidation of zinc cannot be effected practically in the way indicated, it is possible so to act on an oxide of lead as to produce an analogous effect. The Faure battery consists of a strip of lead covered with red lead Pb_3O_4, the red lead, which is an oxide or rust of the metal, being kept in place by a sheet of felt. Two such lead plates having been prepared, they are coiled up together like the spring of a watch. This couple is then immersed in an acid bath and a current of electricity from a dynamo machine is driven through it. After two or three repetitions of the process, it is found that the red lead coatings on the two plates have undergone chemical change, one is converted into peroxide of lead, PbO_2, while the other is converted into metallic lead. By establishing conditions under which the peroxide loses some of its oxygen and the metallic lead gains some, a current of electricity can be obtained at once. Such, in a few words, is the principle of the Faure secondary battery. It contains no electricity, but its parts are in a condition to produce a certain quantity of electricity at will, just like any other battery. The peculiarity of the Faure battery is, it is said, that the current produced is powerful, very large in quantity, and high in potential. But this may be said of many other batteries.

As to the value of such a battery as a mechanical agent, we have to bear in mind first that it creates nothing. It can only give back a portion of the energy expended in producing the chemical change in the red lead, and there is every reason to believe that if employed to turn the best dynamo-electric motor to be had, not more than 50 per cent. of the original energy would be given back. Thus, instead of 1,000,000 foot-pounds in a box of one cubic foot capacity, we should have but 500,000 foot-pounds effective. But the great claim persistently urged for the Faure battery is involved in the idea that it represents vast concentrated energy—that nothing to parallel it in this respect is to be found in the whole world. Thanks are due to Professor Osborne Reynolds, of Owen's College, who lost no time in replying to Sir W. Thomson's statements. "The means of storing and re-storing mechanical energy," writes Professor Reynolds, "form the aspiration not only of Sir William, but of every educated mechanic. It is, however, a question of degree—of the amount of energy stored as compared with the weight of the reservoir, the standard of comparison being coal and corn. Looked at in this way, one cannot but ask whether, if this form of storage is to be the realization of our aspirations, it is not completely disappointing? Large numbers are apt to create a wrong impression until we inquire what is a unit. Eleven million foot-pounds of energy is what is stored in 1 lb. of ordinary coal. So that in this box, weighing 75 lbs., there was just as much energy as in $1\frac{1}{2}$ oz. of coal, which might have been brought from Paris or anywhere else in a waistcoat pocket, or have been sent by letter."

Professor Reynolds here hits the precise point which required hitting. The Faure battery is so far from being a unique and extraordinary storer-up of energy, that its powers are really very insignificant as compared with other arrangements. For example, a cubic foot of water weighs $62\frac{1}{2}$ lbs., and so is 12.5 lbs. lighter than Sir William Thomson's box, although of the same dimensions. To impart 1,000,000 foot-pounds of energy to a cubic foot of water it is only necessary to raise its temperature 20.7°. Professor Thomson may say that the work cannot be rendered available for the production of useful effect, and he is in a sense quite right; but so far as the bare statement that the Faure battery of one cubic foot contains 1,000,000 foot-pounds of energy is concerned, the assertion that a cubic of water when heated 20.75° hotter than it was before, contains 1,000,000 more foot-pounds of energy, is equally true. Again, a cubic foot of air at a pressure of 500 lbs. on the square inch, or 34 atmospheres, contains very nearly 250,000 foot-pounds of

energy, and this in a most convenient form for re-appearing as mechanical power. Owing to the cooling which it will undergo in expanding, a certain loss of useful effect will be incurred, but the compressed air will not lose as much as the Faure battery. It is true that a vessel of four cubic feet capacity would be required to carry 1,000,000 foot-pounds in this way, but the engine and reservoir taken together need not be larger than the Faure battery and its dynamo machine taken together. We might, were it necessary, easily extend this list, and show that the Faure battery has really no claim to be regarded in its present form as much more than an interesting scientific toy. Twenty feet of coal gas will produce an indicated horse power per hour in a good gas engine. There is no trouble whatever in compressing 20 cubic feet into a space of 1 cubic foot. If any one will take the trouble to carry a cylinder full of gas thus compressed from Paris to Scotland, he will be in a position to boast that he has done just four times as much as Sir William Thomson. That gentleman has carried 500,000 effective foot-pounds in his box; but 20 cubic feet of gas condensed twenty times represents 2,000,000 effective foot-pounds. All that Sir William Thomson can do with the Faure battery can be done with common coal gas. We do not know what it costs to charge a Faure battery, but we venture to think that coal gas will prove very much cheaper.

ARCHITECTURE GOVERNED BY TECHNICAL PRINCIPLES.

From "The Builder."

Architects must always acknowledge technical rules to a far greater extent than painters and sculptors. These may, indeed, study with advantage certain principles of composition as practiced by old masters, and they would be none the worse for some knowledge of pigments, and such mechanical details of their art as our Professor of Chemistry can supply. Manual dexterity may also be increased by practice in the schools, but when all this has been done the artist must be left to himself, and his own innate feelings will be his best instructor.

The architectural student, on the other hand, is only on the threshold of his career when he has learned as much as this. He must devote himself to his art as to a learned profession, and though he must base his present designs and future expectations on the achievements of the past, he must study the existing needs of his own time that he may satisfy them, both with art and with common sense. Less unfettered than his brother artists, he has to deal with more intractable materials (to say nothing of more troublesome persons), and attempts at originality prove, in his case, too often to be a snare. It is, therefore, essential for him to deduce, if it be possible, from experience some assistance for his own practice, some principles which may aid him, not so much in imitating successful works as in avoiding errors.

An architect in designing a work of art has always to keep before his mind the *size* and *scale* of his building, the necessity of *stability*, and the method and materials of *construction*, all of which may be described as technical principles of architecture.

In discussing such principles, we will first refer to the element of size. In this respect architecture has an advantage over the sister arts; for the impression caused by the size of an architectural work is, to a great extent, if not altogether, independent of the art displayed in it.

We all know the effect produced upon us by a vast multitude of persons assembled in one place, though we may think little of the individuals composing it. We see a great gathering composed, it may be, of those who seem to us very ordinary and common-place people; we should not perhaps think of submitting our own judgment to any unit of the mass, but size tells, and the feeling has found expression in the saying, *Vox populi vox Dei.*

*A lecture before the Royal Academy, by the late Prof. E. M. Barry, R. A.

A large building will, in like manner, always produce an effect *per se*, and so the quality of mere size is a powerful influence in the hands of the architect. It is, no doubt, one of the lower attributes of architecture, and may to some of us seem of little importance in comparison with the artistic aspect of her work; but the fact, nevertheless, remains, that size is one of the chief elements of architectural impressiveness.

It is usually at first sight that size affects us, as it arouses interest by arresting the attention. If a traveler, entering a foreign town, catches a hasty view of two buildings, a large and a small one, it is to the former that he will first turn his steps. A small work of architecture, however beautiful, will not impress the mind of ordinary observers as much as a building which, from its greater size, is able to multiply parts—it may be, less perfectly designed.

As an illustration of the effect of mere size without any architectural design, we have the Pyramids. Seen from a distance, they are altogether uninteresting, and even when approached, display no beauty of any kind. The form, moreover, with its receding apex, is not favorable to the display of size. The visitor finds, however, that the latter quality grows upon him, and discovers with surprise that the outline which seemed so smooth from afar, is in reality notched with successive steps, and that each of these steps exceeds half the height of a man.

Here we have no architecture, but only a mere mass of large stones piled up in a symmetrical heap. Nothing more inartistic can be imagined, and yet because the heap is a big one, it has impressed, and will doubless continue to impress, the imagination of hundreds of thousands; extorting from them an admiration not to be obtained for structures far more interesting to the architect.

The worship of bigness is, in such an instance, reduced to its elements, and appears, in consequence, common-place and vulgar; but as the principle exists, and the architect has the power to turn it to account, he ought not to neglect it. And this, moreover, should be the case, whatever may be the actual dimensions of the work on which he may be engaged. There are few structures so small that they may not gain by the knowledge of the architect how to make the most of their size; and there can be no building so large that its importance may not be frittered away by injudicious treatment.

To obtain the due effect of size, the architect must study scale. He needs something to mark greatness by contrast. The Pyramids, seen in solitude, appear much smaller than when surrounded by life, and marking their real dimensions by contrast with the Arabs swarming over and upon them. A colossal statue, in the same way, gives no idea of its actual bigness, until an ordinary human being is placed beside it. It then asserts its real importance, just as a great man stands out from among his fellows, because his actions are nobler and better than theirs.

The Greeks did not erect large buildings because they did not require them, and their temples impress us rather as beautiful shrines for sculpture, than as grand architectural monuments. The effect produced in the case of the Parthenon, for example, is by exquisite proportions combined with beautiful detail, and not by size.

The Roman architects, on the other hand, fully appreciated the value of this means of obtaining architectural effect. Large edifices, such as the Coliseum, were the fruit of their energies, and Rome, as the capital of the civilized world, became the center to which all turned in art, as afterwards in religion and literature. The Roman Empire, extending from sea to sea, gave security to subject races, and assured to them material prosperity. Architecture as an art of peace consequently flourished, and throughout the vast empire imposing buildings arose, such as temples, theatres and baths, while public works of utility, like aqueducts and roads, were not neglected.

The Coliseum impresses us at least as much by mere size as by the beauty of its parts. These, indeed, are in no way remarkable, although from their frequent multiplication they give a value to the whole structure, and supply the necessary measure by means of which its vastness may be appreciated.

The great Roman baths are in too imperfect a condition to enable us to speak confidently of their original architectural

effect; but from the remains that have been discovered, particularly of mosaics and sculpture, we have every reason to conclude that their vast size was not thrown away, as has been done at St. Peter's; but that details of moderate dimensions, and statues but little exceeding the size of life, gave that opportunity of comparison which is essential to the architecture of a noble building.

In the Middle Ages we find the same principle worked out, and with even more technical skill. The builders of our cathedrals did not, indeed, aspire to the reproduction of the broad surfaces and spacious vaults of Imperial Rome. They sought to produce architectural grandeur rather by a repetition of parts than by any single exploit. Their works contained details of moderate dimensions, often repeated. The effect of such multiplication of small parts is to give scale to the whole building, and to make the latter appear even larger than it really is.

I dare say some of you, in summer wanderings among the many architectural beauties of France, have suddenly come upon a great church huddled up among mean buildings, clinging to it like parasites. The first sensation is that of incongruity, to be deplored, and, if possible, removed; but reflection and observation will often convince you of the gain of impressiveness derived by the giant structure from the contrast with its pigmy neighbors. The means are, of course, not those which the architect would desire as the best, and it is his part to produce the same result by art, which has been here attained by accident.

We may observe such a result of purely architectural design in some of the great portals which are more the special glory of French than of English churches. In these instances we shall find the door itself to be of moderate dimensions, set as it were in a frame, or rather succession of frames, of great architectural elaboration. Order after order of columns decorates the splayed sides of the recess in which the door is sunk, and between the columns, and in the arches over them, an infinity of small figures and canopies fill the whole surface with details on so small a scale, that they invest the whole composition with an air of size and grandeur unattainable by any other means.

I am now speaking of such designs only as illustrations of the principle under consideration, and apart altogether from the artistic value of the means adopted to carry it out; for, however great may be my admiration for the designs referred to considered as a whole, I have never been able to reconcile myself to small figures tilting forwards in the arches, so that they would fall on the heads of the entering worshippers if not artificially secured in their places by unseen supports. As an illustration, however, of the value of small detail in giving the effect of great size, I know of nothing better than these noble French doorways. If they fail in giving perfect satisfaction, the reason, in my judgment at least, is that they are apparently deficient in another essential principle among the technical rules of architecture—stability, to which we will now briefly turn our attention.

In a world full of turmoil and change, we like to look upon some ancient building, standing as a landmark in the midst of tumult—a rock beaten by the stormy waves in unavailing uproar. To satisfy this requirement, architecture should give us not only stability, but a stability which is obvious, even to the unlearned.

No one who enters Westminster Abbey gives a thought to the sufficiency of the columns and arches. This he is able to take for granted by reason of an apparent superabundance of strength; and though such an appearance may sometimes be misleading, doubts would only suggest themselves to a scientific inquirer, or one well acquainted with defects which may perchance lurk in the construction. It is different with some modern works, the offspring of science alone. Here we find light iron roofs and scanty columns, and wonder how long they will stand, and trust they will do so till we are far away. Or, we are called upon to admire the cleverness of the designer, who has used a less weight of metal than has ever been adopted before. In such cases, stability, in its true architectural sense, is altogether wanting; and when we find ourselves marveling at the mechanical ingenuity of the work, we may be sure that such ingenuity has banished art.

In structures in which the horizontal principle of construction has been fully

carried out, as in Egypt and Greece, the distances between the columns were small, though, as we know by the obelisks and other things, stones of large dimensions could have been procured. The quality of stability was here assured by the obvious preponderance of the supporting element of the design, other considerations, whether of art or utility, being sacrificed to this principle.

From the examination of the past as well as from our own common sense, we may deduce the conclusion that, in architecture, we must insist on stability as an essential principle, not only of necessary safety, but also of art. It is, of course, a common-place that an architect must not allow his buildings to fall down. If he did, he would speedily find himself within the strong grasp of the law. But it is not always equally recognized that, as a question of art, a piece of architecture must look stable, as well as be stable.

The Parthenon not only stands on a rock, but has a plain and satisfactory base line in the steps which surround it. The Romans followed the same rule, or, when they departed from it, placed their columns on a stylobate, which gives in another way the same appearance of stability. Mediæval architects did not attach the same importance to an unbroken base line which it would have been, indeed, difficult for them to have obtained, in consequence of the bold projections of their buttresses and turrets; but they were careful to strengthen the lower parts of their buildings with projections from the general line of the work, and plinths, often doubled and trebled.

It is difficult to overstate the artistic value of a good base line. There may be instances in which great vigor may be sought in height, as in the case of certain forms of towers, such as that of the great Campanile at Venice. A tower thus standing alone makes, perhaps, the most of its height by starting abruptly from the earth. It almost seems to rush upwards from the ground as a rocket might do, without a note of preparation. But setting aside exceptional cases, stability in architecture requires that a building should appear to rest on a secure foundation, and for this purpose demands a good base line.

Common sense tells us that a wall should be stronger and thicker at the bottom than the top, and what is true of the individual wall is also true of the structure as a whole. Architects are required by law in our great towns to widen their walls downwards, and, moreover, to add to their footings, which may even double their thickness, so that walls 3 ft. thick may start with a width of 6 ft. at their first commencement. Where basements exist all this is below ground, but when we approach a building the eye gives no credit for such hidden construction. The building, as far as the spectator is concerned, rests upon the surface of the earth, and unless the design provides in some manner for a satisfactory base, he is conscious of a want in the absence of that obvious stability which we hold to be a rule of art.

We may see the effect of such a base as I have been discussing at the Houses of Parliament. Here we have a building of great elaboration erected upon a plain granite basement, the latter being at times concealed from view by the rise of the tide. The building, owing to the unfavorable level of its site, is not seen to advantage from Westminster Bridge, and can be far more advantageously inspected from the opposite bank of the river. From this point of view the artistic value of the base line can be thoroughly appreciated, and the contrast observed between its presence and absence according to the fallen or risen tide.

The absence of solidity is only too painfully evident in much of the street architecture of modern days. The architect who is called upon to design such work is not to be envied, for under the pressure of commercial requirements, he will too often find it impossible to secure apparent stability in his work, as long as shops exist, and demand great areas of plate glass in their windows, hiding the necessary supports in the shape of some miserable iron bars behind goods or mirrors, which serve to conceal from view their stinted proportions.

I do not suppose that one person in a thousand, who uses these shops, gives a thought to their instability, notwithstanding the warnings which now and again have been given by the sudden fall of such buildings, carrying too often death and destruction with them.

The problem appears hopeless of solu-

tion as long as the conditions of it remain the same. Possibly changes in the current of trade, like those which are now leading to the concentration of business in large establishments, may tend to diminish the importance of the plate glass window in the eyes of the shopkeeper, and so relieve the architect of some of his difficulties.

The French method of laying out blocks of buildings with inner courtyards, approached by covered carriageways with handsome entrances, possesses, independently of convenience, great architectural advantages over our own system of unbroken frontages of plate glass, forming the ground story of our streets.

Architects cannot, however, enforce changes of this kind, however much they may desire them, and in the meantime, all that seems feasible with us at present is to group the upper windows in such a manner as to avoid, as far as possible, the appearance of great central weight, and to make the most of such solid piers as are still permitted or enjoined by the law, in the interests of public safety.

Passing now from the principle of stability, we come to the question of construction, which is, of course, intimately connected with it. It is here that the architect feels in its full force his lack of freedom in contrast with the liberty of his brother artists. While they do pretty much as they like, he must bear a heavy responsibility. His drawings may be as good as theirs, but, unlike them, they are not final, but only a means to an end. It is his duty not to make pretty drawings, but to erect good buildings. After the spirited sketch comes the matter-of-fact builder, who asks how it is to be carried out—to be followed by the estimator, whose dispassionate calculations often chill the enthusiasm of the most hopeful architect, and send a shiver of economy through his system.

If knowledge of construction is thus essential to the architect on the utilitarian side of his art, it is not less necessary in an artistic sense. Not only is it important to know in what positions of a design certain materials may be safely used, but also what will be their appearance and effect. The former requirement applies to the scientific, the latter to the artistic element in architecture. Designs which may be effective in one material will be unfitted for others. Faults of execution may interfere with well-studied detail. Color may be well or ill introduced; magnificence or meanness of effect may be produced by the dimensions or quality of the materials used.

These are all questions of construction, and thus construction becomes one of the leading technical principles which affect architecture. The materials now at the disposal of the architect are, for the most part at least, the same as he has used for centuries. Their qualities have been duly tested, and the limits of their use, with some exceptions, ascertained by actual experiment.

In modern times, the use of iron in construction has, however, been so greatly extended as almost to invest it with the character of a new material, chiefly employed by engineers and shipbuilders rather than by architects; for we cannot rank such buildings as the Crystal Palace among works of architecture. The increased employment of iron has, even at present, added to some of the architect's difficulties, as in that of the top-heavy street architecture to which I have just referred.

Before iron beams were to be readily obtained, the architect could work on the old method of making the walls in the upper part of a building rest upon those of the lower stories. Any reason is now considered sufficient to justify departure from this sound principle of statics, and if the architect venture to remonstrate, his scruples are at once set aside; for is not the iron worker at hand, with his sections of all shapes, sizes, and calculated strength?

I have just referred to the Crystal Palace, and it may, perhaps, be as well to mention it again, as it is the most conspicuous instance we can desire of an iron and purely constructional building. It is not architectural, for it does not comply with the essential principles of architecture. It certainly possesses size, and to this element of impressiveness it owes whatever success can be claimed for it. Stability, in the sense we have been considering, is not attained, and the construction is throughout that of the conservatory building engineer, whose science has been at work, paring down columns and girders to the minimum of necessary strength. Construction is here

all in all, not as we have seen it should be, only the assistant or handmaid of architecture.

I remember when we were told that the Crystal Palace had inaugurated a new era, and that it was only stupid people like architects who could doubt for a moment that our architecture would thenceforth take a new departure. It was useless to point out to a public enamored of a new toy, that not only in stability would such buildings prove defective, but that they even failed from the first in their primary duty of affording shelter.

The architect, accustomed to such permanency in his work, could not regard with favor a so-called system which, by the expansion and contraction of its materials, seemed to its admirers about to establish the principle of perpetual motion, as a novel technical rule of a newly-invented art.

If architects had originally any reason to feel aggrieved at the manner in which their ever-ready teachers assumed their usual position of superiority, the "magic of patience" has shown them that, notwithstanding all glowing predictions, the Crystal Palace has found few imitators, while its unfortunate shareholders have had but too much reason to ponder over the question of stability, in connection with the cost of repairs. From this and other specimens we do not, it must be confessed, derive much encouragement to expect new and speedy developments of iron architecture.

THE SECONDARY STRAINS IN IRON STRUCTURES.

By DR. E. WINKLER.

From "Deutsche Bauzeitung" for Abstracts of Institution of Civil Engineers.

The calculation of strains in triangulated systems (girders) is generally performed as if the bars were joined at their ends by hinges offering no frictional resistance; so that, when the system deflects in consequence of the lengthening and shortening of the bars, and the angles of each triangle change accordingly, the bars retain their condition of being straight. This is not the case in reality, especially in girders with riveted connections. The bars are compelled on the one hand to retain their angles towards each other at the junctions, and on the other to follow the altered positions of the corners of the triangles, the consequence being the bending of each bar with generally one point of contrary flexure, and the occurrence of transverse strains (*secondary strains*) in addition to the axial strains (*primary strains*).

If S be the axial or primary strain in a bar, F its sectional area, J its moment of inertia, v the distance of an extreme fiber from the neutral fiber, and M the bending moment, then N, the maximum strain, is:

$$N=\frac{S}{F}+\frac{Mv}{J} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

If further a be the length of one side of a triangle a_1 and a_2 the projections upon it of the other two sides σ, σ_1, σ_2, the rates of changes of length of the corresponding three sides, h the height of the triangle measured from a, then the change of the angle opposite a is:

$$\Delta a=\frac{1}{h}(a\sigma-a_1\sigma_1-a_2\sigma_2) \quad . \quad . \quad (2)$$

If finally τ is the angle which the end of a bar in the bent state forms with the straight line between the ends of the bar (*deviation angle*) so that τ_1 and τ_2 are the two deviation angles of a bar having a length $= l$, a moment of inertia $=$ J, and a modulus of elasticity $=$ E, then the moments at each end of the bar are:

$$\left.\begin{aligned} M_1 &= \frac{2EJ}{l}(2\tau_1+\tau_2) \\ M_2 &= \frac{2EJ}{l}(\tau_1+2\tau_2) \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad (3)$$

The process of calculating the strains is now as follows: By means of equation (2) all the angles in the system after the deflection are ascertained, assuming that the bars remain straight; then, since the angles between the bars at their ends re-

main unchanged, there would, in the expressions for the deviation angles of the bars of the same junction, be only one unknown quantity, viz., the deviation angle (τ) of one of the bars. By applying these equations (3) to each bar at one point of junction, and considering that the aggregate of the moments for that point must be $= 0$, and, by doing the same for each point of junction, so many equations are obtained as there are unknown deviation angles τ. By putting these values into equations (3) all the moments are ascertained, and consequently by means of equation (1) the strains are found. This solves the problem. For the calculation of examples, equation (1) can be brought to the following form:

$$N = m \frac{v}{h} k \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

where k is the primary strain, h the depth of the girder, v the distance of an extreme fiber from the neutral fiber, and m a coefficient dependent on the geometrical conditions of the structure. The formula establishes at once the rule that the bars in a girder should not be too broad. Calculating m for various examples, the author finds a number of results, some of which are as follows:

Warren girder—single system, broad flanges and narrow diagonals (*i. e.*, measured in the vertical plane); m (for flanges) $= 2$; m (for diagonals) $= 6$ to 12.

The same—narrow flanges and broad diagonals: m (flanges) $= 1.0$ to 1.4; m (diagonals) $= 5$ to 14.

Panel girder—single system, broad flanges; m (flanges) $= 2$; m (diagonals) $= 8$ to 14; m (verticals) $= 17$ to 20.

The same—narrow flanges; m (flanges) $= 10$ to 23; m (diagonals) $= 1.7$ to 3.1; m (verticals) $= 3$ to 5.

Putting m into equation (4) it is found, for example, that the secondary strains in the end verticals of panel girders may amount to 30 or 35 per cent. of the primary strains; and further, as a general result, that panel bridges contain greater secondary strains than Warren or lattice girders.

Lattice girder—parallel flanges, double system; diagonals free at crossings. This is generally under similar conditions as the girder with a single system, but at the ends the secondary strains amount to about 40 per cent. more.

The same—diagonals rigidly fixed. The secondary strains are in the center about 13 per cent., and at the ends about 70 per cent. of the primary strains. This is very much increased if only one system is loaded, viz., in flanges to the 3.5 to 12 fold, and in the lattice work to the 2.5 to 5 fold; but if additional narrow verticals are introduced, the strains are the same as if both systems were loaded.

Girders with polygonal flanges are advantageous, on account of the diagonals and verticals being narrow. The secondary strains in parabolic girders with single system amount to only 8 to 12 per cent.

Systems with hinged connections. Here is:

$$N = \tfrac{1}{2} f \frac{d\,v}{r^2} k,$$

d being the diameter of the pin, r the radius of gyration of a bar, and f the coefficient of friction. For rectangular sections and $f = 0.16$

$$N = 0.24 \frac{d}{v} k.$$

This applied to some existing bridges, gives secondary strains not inferior to those with riveted connections; but the advantage of pin connections is that the vibrations from the moving load probably overcome the friction to some extent, and that consequently the secondary strains due to the fixed load need not be taken into account. In bridges with riveted connection an artificial mode of erection would be required to produce a similar result.

THE *Archiv der Pharmacie* gives the following formula for making paper for wrapping up silver: Six parts of caustic soda are dissolved in water until the hydrometer marks 20 deg. Beaume. To the solution add four parts of oxide of zinc, and boil until it is dissolved. Add sufficient water to bring the solution down to 10 deg. Beaume. Paper or calico soaked in the solution and dried will effectually preserve the most highly polished silver articles from the tarnishing action of the sulphuretted hydrogen which is contained in such notable quantities in the atmosphere of all large towns.

ACOUSTICS IN ARCHITECTURE.

By A. F. OAKEY.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

OUR momentary dependence upon the sensations of our ears is perhaps only appreciated by those who have been deprived of hearing, whether for life by disease or accident, or for a time by the faulty construction of theaters, concert halls, lecture rooms and churches. The habit of not hearing, of not marking that Falstaff was conveniently troubled with when Justice Shallow demanded his £1,000, has to a great extent become the unaffected cause of somnolence in the occupants of pews, fatigue in play-goers and a lack of enthusiasm in musical audiences. A performance or a discourse must be powerfully interesting to hold the attention to the end, in an apartment where one is at times not quite certain that the sound has reached as it was delivered, and at times certain that it has not. After a few moments of this painful exercise one relapses into an indifferent state of mind, soon followed by sleep or irritable fatigue, neither of which conditions tend to increase our respect for the entertainment. We have all heard speakers and witnessed performances for the second time in a different place with very different feelings of pleasure, often modifying our opinions of the performance accordingly; and it can be shown that there are places of amusement in which no performance, however attractive in itself, has succeeded, and churches in which no preacher, however eloquent, can make himself felt. For the mysterious disadvantage in these cases all manner of causes are discovered; but eliminating those cases in which the disadvantge is thought to be one of location, of ventilation, or what not, we still have a number in which the disadvantage is plainly in the difficulty or impossibility of hearing distinctly, and without fatiguing mental effort.

To remedy this defect, and to discover a system by whose application to any circumstances we may be certain of acoustic success, has been one of the scientific aspirations for ages.

WITH THE ANCIENTS

the problem was a much simpler one than we have to solve, because all that they attempted or desired to achieve was the reinforcement of the voice in the open air, their theaters being only covered with a velarium when necessary, and the performers chanted their parts in a monotonous key to thousands of listeners, seated in rising tiers surrounding the stage on three sides, in rather more than a semi-circle. The necessary reinforcement to the voice was given by a very beautiful and simple expedient of three cones, placed in a central position so as to be in the same relative position to the player as he moved about on his semi-circular stage; there were bells hung over the cones, and so hung that they could be raised or lowered at pleasure, the cones filling more or less of the interior of the bell. These bells had each a tone peculiar to itself, the three together forming a chord, to include the compass of any recital, and by raising or lowering the bells they could be made to answer to all intermediate tones or semi-tones. In this way a resonance was produced that was always in unison with the voice and redoubled its apparent force. This expedient has been used in later years with some modifications, jars or vases of pottery being substituted for the bells and cones, and these vases were built into the walls and roofs of churches, always at certain angles with the position of a pulpit, so that a preacher should find it less difficult to make the echoes in his exhortations. But these experimentc were found to cause more annoyance from reverberation, than was balanced by the resonance they gave the voice. Examples of this acoustic pottery are found in St. Peter's at Norwich, St. Mary's at Youghal, and in many old churches on the Continent; in the latter, the jars or vases often being placed under the stalls of the choir, with the idea that their sonorous vibrations would be more

easily excited and sustained by the vibrations of the wood of the stalls. In St. Clement's, at Sandwich, the jars are built into the north and south walls of the chancel, close under the roof plates, as if with the intention of sustaining the resonance of the roof timbers. But all these contrivances were found to be inadequate, and the innumerable phases of the sounding board began to make their appearance, every possible form, size and material being placed in every conceivable relative position to the speaker; but there are no instances in which the defects thought to be remedied by these contrivances have been more than partially cured, while, in many instances, these experiments have only made confusion worse confounded. Of course, in every difficulty, reasons are as plenty as blackberries, and every conceivable experiment was tried without ever striking at the root of the evil, until physiology came to our aid, explaining how and why it is that we appreciate the sensation we call sound. And it is only within the last fifty years that buildings have been designed and built with a view to acoustic properties from the first. There are a number of more or less plausible theories now under discussion in professional circles, and the object of this essay is to explain the one of which I am the advocate. It will be necessary for me to state a few

PHYSICAL AND PHYSIOLOGICAL FACTS

with which most people are already familiar, as a corner stone to my theory, but I shall be as brief as possible.

Sound is the sensation of the auditory nerve when the air surrounding us is set in motion with sufficient force. There are two kinds of sound, musical tone and mere noise; the first being the result of a regular movement of the air—a movement that strikes the drum of the ear at regular intervals, producing a continuous sensation or note of the scale. The second (noise) is an irregular movement of the air, a movement that strkes at irregular intervals, producing not a continuous but a confused sensation. All individual sounds are musical tones, and consequently all noises are made up of musical tones, but there are innumerable combinations of musical tones that are not noises, because in these cases the intervals of vibration of each of the tones bear a simpler ratio to the intervals of vibration of the other tones—a ratio so simple that it is at once appreciated, and a continuous sensation results; while in a noise the intervals of vibration of the tones bear no commensurate simple ratio, and a confused sensation results. In musical com binations of tones the commensurate ratio that the intervals bear, is always expressible by the numbers 1, 2, 3, 4, 5 and 6. The minor sixth employs 7 also. Beyond this our ears cannot appreciate the ratio and dissonance results. The notes of the scale are determined by the number of vibrations in any given tone peculiar to each; for instance, the lowest note of a seven octave piano-forte makes $16\frac{1}{2}$ vibrations per second, and the highest 2112. Our ears can appreciate both lower and higher tones than these, but we have all felt the discomfort of the sensation produced by the lowest note of some church organ, seeming to make the whole building to tremble with its $16\frac{1}{2}$ vibrations per second, while the notes having more than 4000 per second are so sharp as to be painful and even injurious to the drum of the ear.

In the construction of all musical instruments, the object aimed at is to generate at pleasure, in the instrument, any one of a scale of notes, and to so reinforce that particular vibration as to transmit it to the air with sufficient force to convey it to our ears. The object of having a number of instruments of different materials and different forms of construction, is to produce different qualities of sound. The number of vibrations only determines the pitch of the note, but the quality is determined by the kind of vibration. A piano-forte string may vibrate from a stroke of the hammer 132 times back and forth in a second, producing the sensation we call the middle C, and a trumpet may be blown so that the vibrations of the air are the same in number. The notes are then in unison, but we easily detect the difference, owing to the different materials and means employed, and the consequent different nature of the movements. My reader will ask what has all this to do with the acoustic properties of buildings? But I must dwell a little longer upon musical instruments, be-

cause upon the facts I have stated, and upon a few more, rests the theory I am going to explain.

Of all

MUSICAL INSTRUMENTS

the violin is admitted to be the most perfect; that is, those made from one to two hundred years ago by Stradivarius, Nicholas Amati, Julius Guananius and a few others. These instruments show the most scientific application of acoustic phenomena. For instance, every piece of wood, according to its length, breadth and thickness, will answer to some note of the scale; that is, fine sand or powder scattered over the surface will range itself in regular patterns when the wood vibrates in sympathy with a certain note, and these patterns are always composed of parabolic curves. The vibration of a string sounding any note describes parabolic curves on either side of its natural straight position. These facts are beautifully applied in the construction of the violin. The top table is composed of light porous deal, the vibrations of whose fibers are rapid and easily excited, and this top table is pressed and bent so that its convexity describes a parabolic curve, and exactly that curve which a string would describe in sounding the note peculiar to this piece of deal. Again, the bottom table is made on the same principle, only being of maple, a harder wood, and consequently less easily excited to its slower vibrations; that is, the note of the top table is of a higher pitch than that of the bottom table, and this difference in pitch was always one whole note of the scale. Now, let us examine the interior of the instrument and see what results from this disposition. The convexities of the top and bottom tables without become concavities within, and the sound is reinforced as by two parabolic reflectors with a common axis, so that this little instrument can fill a spacious hall with its sonorous pulsations, originating in merely passing a few stretched horsehairs across the dried entrails of an animal.

But these principles alone do not constitute a fine violin. Exhaustive experiment shows it all important that the interior space be neither too long, too wide nor too deep, and we find in the finest instruments that these dimensions always bear a simple commensurate ratio expressible by the numbers 1, 2, 3, 4, 5 and 6; in fact, the same ratio that exists between the tones of a consonant chord. All this nice adjustment is merely to the end that each sound as it is produced, may be encouraged and reinforced so that it may be heard at a greater or less distance; but it must not be altered in the least in its pitch or quality, or the instrument is a failure and utterly worthless. Then, what goes on *in* this little instrument, is really what we are striving for in our halls, theaters and churches. We want the air to vibrate in exactly the same way throughout. Hearing correctly is simply the movement of the air in force and rapidity, being exactly the same when it strikes the drum of the ear as it was when it received its first impetus from mechanical appliances, or a human voice.

AIR

does not transmit sound by one vast vibration in its whole extent, but by a number of particles, each vibrating in exactly the same way, and with the same number of oscillations in any given time. The first impetus from the initial vibration may be from 6 inches to 32 feet unchecked, according to its velocity, and according to the extent of the resisting body of air. But this first movement recoils after imparting its waning force to the next space, which, of course, will be smaller; and that again, the movement being passed on in this way theoretically for ever, and the whole combined movement or passing tremor is figuratively called a wave of sound. Now, it is plain that inasmuch as the extent of the body of air determines, according to the initial velocity, the length, breadth and depth of the first unchecked movement, it is important that the extent in any one direction should bear some proportion to the force of the movement in that direction. For instance, in a room ten feet high, ten feet wide and fifty feet long, a listener at the end would hardly appreciate the same sensations as a listener at one side who should be within ten feet of the sound produced. Of course a sound has more force in the direction it is delivered, but this force

ears a certain proportion to the force in other directions; as, for instance, the average speaker can be heard at a distance of 90 feet in front or in the direction he speaks, 75 feet on each side, 30 feet behind, and 45 feet vertically. Taking any three of these figures we have 90, 30, 45, or 6 : 2 : 3; 90, 75, 45, or 6 : 5 : 3; 30, 75, 45—2 : 5 : 3, or always harmonic proportions. These proportions must exist in the first movement, or first disturbance of the air, or these distances as given would be incorrect, and if these proportions are true for the first movement they must be so for every particle of air that passes the sonorous tremor on to the next particle in any direction. Let us assume that the first movement from the mouth of a speaker, or from an instrument, is in one instance two feet in the direction it is delivered, then applying the proportion or ratio already given, we have 2 ft. $\times 1'.9\frac{1}{3}'' \times$ 1 ft., and the figures will always retain their ratio while they diminish for each succeeding space. But how can this natural proportion be maintained if the resistance of the air in these different directions is not this proportion? Supposing, as is often the case, that the speaker faces in the shortest direction? Then the resistance in that direction is much less than laterally and vertically, while the force in that direction is greater; consequently, before those persons seated near the side walls have heard anything, those seated beween the speaker and the wall opposite have not only heard but have received an echo from the wall behind them. If we suppose this defective disposition to be changed for

A HALL OF HARMONIC PROPORTIONS,

in which the speaker delivers his voice as he should in the length, we will be much better off inasmuch as the sounds will be appreciated at all points with the same intensity, but we still have to deal more or less with that opposite wall and its echoes. Now, inasmuch as a vibrating body of air is spheroidal, it is plain that the angles of an apartment, the angles of wall and wall, or ceiling and wall, are a disturbing element; but in curving them we must adapt a curve that will not plunge us into new difficulties. Apartments have been built with a semicircular end and a cove cornice of a quadrant, resulting, of course, in a mere whispering gallery; others, like the Albert hall in London, have been elliptical in plan, and with an elliptical ceiling, resulting, as a matter of course, in the most exaggerated reflections at either focus of the ellipse. In our violin there is no such difficulty because the curves are parabolic, and in such curves the reflections are always parallel to the axis. Applying this, let us suppose that our hall is planned in harmonic proportions—meeting our first difficulty. Then let us suppose that the wall opposite the speaker or orchestra is a very gradual parabola in plan, so gradual that the focus is very near the wall; and let the cornice and wall vertically be half this same parabola and the result is that there is only one point on the floor near the wall where there is a possibility of a reflection—that is, at the focus; for the end of our hall is formed by the parabola we have chosen, describing half a revolution on its axis. There are still many more difficulties that beset us, and not the least is the combined result of

THE UPWARD TENDENCY OF SOUND

in an apartment, and the absorbing surface an audience presents with their clothing. It is not because you are at a greater distance, in your back seat, from what is going on that you cannot hear well, it is because there is a quantity of material in dresses, coats, bonnets, &c., between you and the performance, and because the sound is rising with the exhalations of all these people until it passes far above your head, as you sit on a dead level with your nostrils presented to the entertainment in the vain attempt to see if you cannot hear. There is no disadvantage to a listener in being at the farthest end of an apartment if only he has nothing but the air, and pure air, between his ears and what he listens to. I say between his ears, because that average height must determine the difference between the level of his seat and that of his neighbors in front. In other words, there should be not less than six inches, and, if possible, nine inches difference in the levels of the seats, so that they may rise in a gradual line from the first to the last. Wherever this has been done, as in the lecture hall of the University of London, it has proved success-

ful. On the other hand, how many halls with level floors are not utterly bad acoustically, whatever other advantages they may have, and these rising tiers also prevent any possibility of echo. There remain three important points to determine: Ventilation, materials and the treatment of galleries, where they are necessities.

The purity of the air in an apartment is more important to our health and comfort than to our sense of hearing. The ventilation of an apartment only influences its acoustic properties in two ways: 1st. The currents of air, or the general direction of

THE SYSTEM OF VENTILATION

adopted, should be in the direction of the sound toward the audience, and the foul air exits should be ampler to prevent strata forming of a greater density and heat than elsewhere, as such conditions transmit sound more slowly, and retardation means confusion. Cross draughts, if only strong enough, will render all sound indistinguishable; so that we have only one system to depend on—that of introducing our fresh air heated to a proper temperature, at the end of our apartment opposite the audience, and introducing it at as low a level as possible, while our foul air exits should be in the riser of each row of seats, and the hot air exits as high up as possible at the farther end, thus creating an upward and onward draught in the direction we desire the sound to travel, while we insure to every one in our rising tiers of seats a constant supply of fresh air from in front. In regard to the

MATERIALS THAT SHOULD BE USED

in finishing the walls and ceiling of an apartment, no inflexible rule can be laid down. While we may be quite certain as to the best method in any particular instance, the peculiar properties of all available materials being well understood, our choice of a material must depend upon one fact that is seldom the same in any two apartments, namely, the relative capacity—that is, the number of cubic feet of space for each person. The most exhaustive experiment has determined that when the number of cubic feet of space for each person exceeds 195, it becomes necessary to adapt a resonant material for ceiling or walls, or both; that when the space exceeds 210, both walls and ceiling should be of wood, and the greater the space per head beyond this, the softer and more porous the wood must be, and the greater the necessity of perfect construction, so as to preserve the continuity of the fiber, and the thinner the wood employed should be, the necessity always increasing for an air chamber back of this wooden surface, as the proportion of space increases. In other words, the greater the proportion of space to the number of hearers the more the necessity of lining the apartment with sounding boards. On the other hand, when this proportion is less than 195 feet per head, it becomes necessary to present a repellant, hard and unsympathetic surface like plaster; and should the proportion become less than 150, stone or an artificial stone becomes necessary, and even an iron plate ceiling has been found advantageous, provided the metal is in small plates and sufficiently thick to be excited with difficulty. All these facts are equally true of the floor surface, but there we have more control, always being able to provide a space below, to leave the floor uncovered or to deaden it with carpeting, and fill up below with deafening. This question of material is exemplified by the violin, with its subtle distribution of hard and soft woods of varying thicknesses.

There are many instances in which galleries become a necessary feature in an apartment, whether the apartment is used as a lecture room, concert hall, theatre or church, and therefore it has become necessary to contrive

SOME MEANS OF CONSTRUCTING GALLERIES,

so that they may not, as they certainly are likely to, render useless the nicest applications of acoustic science. Persons seated under a gallery seldom or never hear distinctly, because the air under the gallery is not set in motion at the same time as that in the open space. It is a system apart, and only becomes affected after the body of air in the open space has committed itself to a certain form of vibration, while it affects the air in the open space, inasmuch as it is not an impervious body like a wall, but simply a more confined and a less proportionate

body from its form. No worse form for consonant vibration could well be devised than the space under the ordinary gallery with its ceiling slanting upward and backward to an acute angle at the wall line, while its natural disadvantages are generally much increased either by the accumulation of bad air in this confined space, or by a direct cold draft from behind, tending to check all possible influence from the sonorous tremor of the air in the main central open space.

I cannot see why all these difficulties cannot be obviated by a simple contrivance which, at the same time, abolishes another nuisance accompanying the usual gallery—that of the supporting columns, one of which, wherever your seat may be under the gallery, is pretty sure to range itself between you and what you are looking at or listening to. The contrivance I speak of is merely to construct a gallery upon a system of curved iron supports which should begin on the floor line against the wall, and with a gradual curve outward as they rise; any desired projection can be obtained and the construction rendered perfectly safer by a system of stays at various points and at various angles back to the wall. The curved supports or ribs would, of course, occur at regular intervals, and the spaces between them should be filled in with wood or plaster surface, always following the curve of the ribs, and thus forming a grand cove in compartments, giving an opportunity for decorative effect not presented by the wall and ceiling under the usual gallery. Of course the curve should be parabolic for the same reasons already given, and should bear the proper proportion to the main curves employed in the construction of the hall. This contrivance at once obviates the disadvantages of the usual form of gallery in seeing, hearing and breathing, while it can be made to simplify the ventilation by providing hot air exits through perforations in the upper part of each panel of the cove, and thus leaving the air in the gallery above as equable as elsewhere, instead of its being, as is usually the case, a mere stagnant strata of the heated air from below. These perforations in the cove properly connected with the foul air shafts of the building may be made to draw with certainty by the disposition of the chandeliers, which should be hung all round the house on the extreme projection of the cove, at regular intervals, so that the heat rising from the lights finds its escape through the piercings in the cove, causing them to draw. This disposition at the same time obviates the annoyance so constantly felt from a large glaring central chandelier.

Reviewing the facts as I have stated them, I can see no excuse for building an apartment so that its acoustic properties are not as much a matter of course as keeping out the weather. There can be no instance where the principles I have briefly described cannot be applied, whether the apartment be a theatre, concert hall, lecture room, church or court of justice. There cannot be an instance of an apartment whose acoustic properties are defective, however fundamentally, where the defects cannot with certainty be remedied. Other considerations for other parts of the building would sometimes have to be sacrificed, of course, where the defect was one of dimension in some one direction; as, for instance, the raising of the ceiling of the room would involve the sacrifice of the room over head, unless the roof were also raised. But of one thing we can be certain, that the defects of two apartments are never exactly the same, and the alterations, additions or appliances that serve our purpose in one instance, will, in all probability, prove useless in another.

THE ACOUSTICS OF BUILDINGS

is a science with which intention has nothing to do; each problem must be studied by itself, and every possible contingency must be weighed and settled by some application of the few simple laws we have to depend on. There are many apartments that are agreeable to a speaker and to his audience, while to a musician and his audience they are more or less annoying, and this is easily understood, because the vibrations produced by speaking are not of so prolonged or regular a nature, and consequently cannot cause nearly so much reverberation. But, on the other hand, there is no instance of an apartment where music is heard to advantage where a speaker does not find himself free from restraint, oppression or a necessity for exhaustive exertion. Therefore, our problem is

plainly to build our apartment, whatever it is intended for, as if it were a music room, and we are safe. It is no matter what the general form of the space we have to deal with may be, we can always increase or decrease some one or two dimensions until we can fix upon some unit of measurement that shall express the proportions in some harmonic ratio. If our apartment is of necessity 100 feet long and 50 feet wide, we can take 25 as our unit, and by making our ceiling 50 feet high we have the ratio 2:2:4; or assuming any two dimensions as fixed, say the height 50 and the length 100 then we can make our width 75, using the same unit, and we have 2:3:4; or, supposing the height and width fixed each at 50, then we can take 75 as our length and have the same ratio 2:3:4, only differently applied. It would be easy to show that harmonic proportions are always attainable even

IN ALTERING OLD BUILDINGS;

and these often present defects that almost incline us to think that their designers were perfectly conversant with acoustic law, and had ingeniously contrived to violate every principle.

I remember doctoring a church in which the pulpit was placed at one side, so that the speaker threw his voice directly against a hard finished wall opposite, and the ceiling was wagon headed, that is, rising from the wall at an obtuse angle and forming another angle at half its distance from the center, so that there were two rows of panels either side of the center forming the ceiling and forming angles with each other and with the walls; these surfaces were also plastered in hard finish, and, consequently, the sounds were reflected from the wall, and again from the ceiling in a most complicated way, causing three distinct echoes at certain intervals that interfered with and rendered the exhortations of the preacher more or less ambiguous to those within certain distances, while those who sat at either end of the church heard a great deal going on without being able to distinguish anything. The organ was placed in a gallery at one end, and found great reinforcement from the wagon-headed ceiling. On measuring this church I found that it would only be necessary to lower the ceiling 2 feet, alter the paneling to 3 panels on either side of the center, finish them in hard wood, and make them form angles with the walls and with each other, so that their surfaces were tangent to the parabola I had used as a basis. Then to move the pulpit to the end opposite the gallery, make the pews face the pulpit, and the thing was done. Since this alteration our clergyman has preached to the congregation, who before were never satisfied with any one for more than a few months.

Two years ago I found a room in the town hall of a village in Massachusetts, in which meetings of all sorts were held, musical entertainments given and church festivals celebrated. This room had serious acoustic defects which were the result of two causes: 1st, according to the theory I have explained, the room was too wide for its height and length; 2nd, there was too much repellant surface in the hard finish plaster for the capacity of the room. At this time I was engaged in experiments of all sorts that related to acoustics, and as the cheapest means of remedying the defects of this room I had, with the authorities permission, plain pine shelving built up to the ceiling on either side of the room, making the shelves the necessary depth to bring the room into the proportions of 3:4:5. I then persuaded the managers of the town reading room to use the shelves to stow away old files of newspapers and periodicals which gave me the absorbent surface I wanted, and now the room is admitted to be acoustically a success.

When we understand the origin of the sensation we call sound, and the properties of the materials used in building, the guarding against this or that special contingency becomes extremely simple. In the City of New York, and in any locality where houses are built with party walls instead of each house being self contained, much annoyance is experienced by the intimate knowledge one is forced to acquire of the neighbors' habits owing to the transmission of sound through the party walls, and this is so appreciable that in some houses I have seen it would only be necessary for the neighbors on each side to give simultaneous musical entertainments, not only to make sleep impossible, but even to oblige one to exert the voice to be heard in conversation.

In one instance I know that legal proceedings were contemplated to restrain the occupants of a young ladies' boarding school from playing upon fifteen pianos at once, all of which were placed against the plaintiff's party wall. Whether the law was found to cover such a nuisance I have not heard, but if the suit could be brought I think one's sympathies would be with the plaintiff.

This sort of nuisance arises from two causes—niggardly economy, both of space and money, and, secondly, ignorance of the nature of materials. Of course, if space were unlimited, a brick wall could easily be built whose thickness would render it impervious, but the problem is to build the thinnest possible wall that will carry itself and its load, and that will not transmit sound.

We know that almost any material is a better conductor than air, and that if we can provide a sufficient air space with comparatively non-conducting material on each side, no vibration would be transmitted, but we can do better by dividing our air space by non-conducting material. In fact, this disposition is forced upon us by our lack of room. The trouble arises from plastering directly upon the brick, thereby saving the lath and one coat of plaster, as well as one inch in the width of the rooms.

Supposing the wall to be only eight inches of brick, which is too often the case, the sound would be more effectually checked by furring (that is, nailing strips all over the surface) and then lathing and plastering, than by increasing the thickness of the wall to 12 inches with the plaster on the bricks; because with our furring, the vibration has to pass through the plaster, the lath, and air space, the brick, another air space, and again the lath and plaster; and to do this the vibration must be unusually intense and sustained. The inch in the width of the apartments, and a small amount of money is sacrificed by this preventive measure, but how much comfort is gained? There is still one minor, but very appreciable cause for the transmission of sound through party walls that I have not mentioned; the injurious practice of giving the floor joists a bearing in the walls, however thin the walls may be; in fact, some rows of houses could not stand till their roofs were put on if the walls had not this assistance. But it is easily seen that when the joists are let into a thin wall on both sides that there can be little to separate them, and that the continuous fiber of the wood passes a vibration so readily that in a row of five or six houses so built, a blow upon the side wall of the last house, on the line of a joist, would be distinctly heard on the wall at the other end of the row. This objection is easily overcome by a better though somewhat more expensive mode of construction, but one that does not increase the thickness of the wall. The joists being carried by a few projecting courses of brick on each side, so that the whole thickness of the wall separates the ends of the timbers.

To return to my first enquiries, I shall explain the peculiarities of one or two existing buildings in illustration of my theory. Probably the most successful building acoustically that was ever constructed was

THE THEATRE AT LYONS,

built by the architect, Sufflot, in 1754. I say was, because it was burned and reconstructed—burned in 1826 and rebuilt in 1831. As it now stands it is bad, acoustically, the owners believing that they could make some improvements in plan. The drawings of the original theatre, now preserved in Paris, completely corroborate the theory I have explained, while the theatre as it is violates it in several important particulars. The original theatre was in the harmonic proportion of 4 : 4 : 3. The present theatre is not in harmonic protion, and employs circular curves to a great extent.

The Albert Hall in London is an example in violation of my theory, and has been heavily draped to prevent the complication of echoes resulting from the elliptical form adopted. It is the largest place of amusement under one roof in the world, being 219 feet long by 185 feet wide, and 136 feet in height. A glance at these figures satisfies us that no commensurate ratio exists that is expressible in the numbers 1 to 6, and beside this fact, I have already mentioned the objections to the ellipse, where curves are employed.

The probable acoustic result of this place was pointed out by many acoustic

authorities in England before the building was begun; but as Captain Foulke, an engineer, had drawn up a description of the building, using the word "elliptical" in a prospectus, upon the strength of which subscriptions to the stock were received, it was found that any radical change would vitiate the preliminary preceedings, and so two million pounds sterling, more or less, were invested in a building which was certain from the outset to be a failure in the most important requirement.

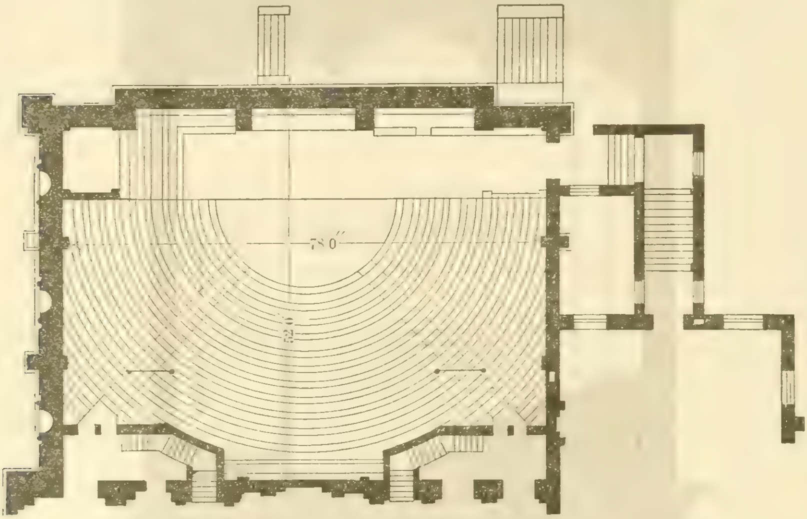
The Free Trade Hall in Manchester is an example of a successful building, acoustically. The dimensions are 130x78 and 52 feet in height, or with a unit of measurement of 26 feet; the harmonic proportion 5:3:2. The floor also rises from the platform to the rear wall, which is an exceedingly flat curve in plan. The exact nature of this curve I am unable to state; but from the published drawings it is not circular. The angle of wall and ceiling is also treated with a very gradual curve. There is a shallow gallery on two sides and one end of the hall, but the lobbies are placed under it, so that the objections that I mentioned to the space under a gallery are obviated.

IN THIS COUNTRY

we are not rich in acoustic successes, but the Boston Music Hall may be quoted as probably the best example we have, and this was built by the Boston architect, George Snell, who has adopted harmonic proportions, though the requirements did not admit a rising floor.

The Cincinnati Music Hall is considered by all musicians who have performed there to be at least as perfect acoustically as any American example. The interior of this hall was constructed from my plans, submitted in competition, and is—as nearly as the dual purpose of the building would admit—a realization of my theories as herein explained; length 200, height 80, width 120; or 2:3:5. Every room has a key-note—that is, there is always a note that creates more resonance in any particular room than any other note, and this fact should always be taken into consideration by a speaker or musician. If the key-note of a room is discovered. which is easily done, a speaker will find that his audience will hear better, and that he will find it less tiresome to talk in that key an octave above or below as best suits him. The old Salle de Concert in Paris is particularly sensitive in this respect, and has become like an old violin, being lined with wood that is always seasoning, and responds readily to the vibrations of instruments and voices.

Slight projections on walls and ceilings are in some instances advantageous,

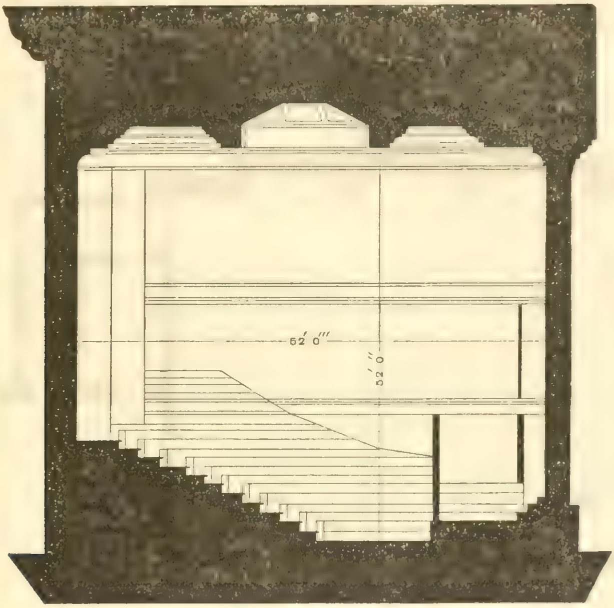


PLAN

Fig. I.

where too much resonance is created; but this consideration is involved in determining the finish to be adopted. The object of a projecting cornice, or pilaster, may be to thicken the wall at that point, so as to check a continuous tremor passing along the whole surface, as is the case in a whispering gallery.

The first illustration is a plan of the lecture room of the University of London, which shows the disposition of an audience in a semicircle though position of wall-surface which is ingeniously treated in plaster and wood, gaining a happy distribution of repellant and resonant material that has proved most satisfactory. This room has never, I believe, been used for music, and I am inclined to think that it would not be so successful as a music hall, because it is found that where the opposing wall is as near the singer or orchestra as the side walls, echoes or confused reverberation is apt to result from the reasons I have



LONGITUDINAL. SECTION.

SCALE. 10′ 0″ 20 30

Fig. 2.

in a rectangular room. This, room is found to be a success as a lecture room, and it will be noticed that on any radiating line from the speaker the distance is the same to the farthest listener, and that the proportion of length to width is 78 to 52. The cross section (Fig. 2) of this room shows the rising tiers of benches, giving each auditor the same opportunity, and the height of the room is again 52; recalling the dimensions of the plan 78x52 we have the ratio of 2 : 2 : 3, with a unit of 26. The longitudinal section (Fig. 3) shows the dis- stated, especially if the wall is at right angles with the side walls; in other words, for musical purposes the sound should be delivered in the length, and should be met by a wall that is more or less curved.

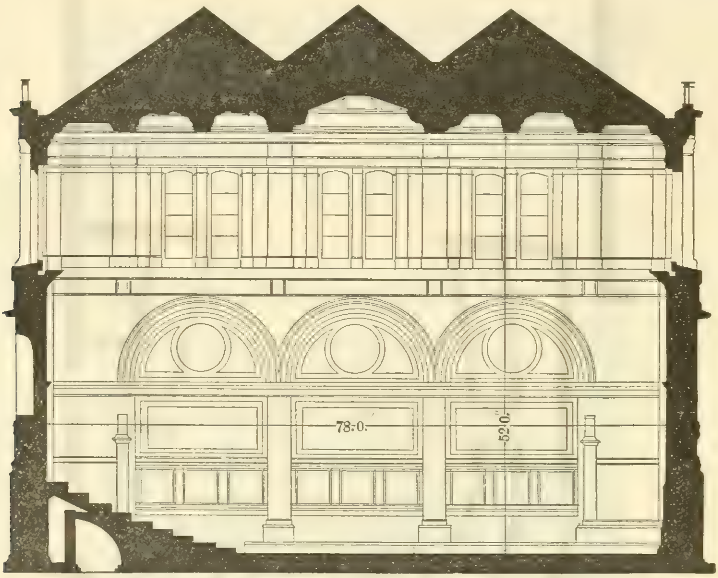
Her Majesty's Theatre, Haymarket, (Fig. 4) is our bad example, and I need hardly explain why after what I have said. This illustration shows the plan as a horseshoe, 67 feet in length and 56 feet at its greatest width. The curve is circular. The section (Fig. 5) shows us an ingeniously bad contrivance for the

highest gallery, but the boxes are an advantage, as they tend to break up the surface and prevent the confusion that would arise from the form employed. The height is 57 feet, and with the dimensions already given—67 x 56—no commensurate ratio can be discovered. This theatre was always difficult to speak or sing in.

Figs. 6 and 7 illustrate my design for the Cincinnati Music Hall as I submitted it to the committee on preliminary studies; and Fig. 8 illustrates the plan of the hall as it was built. All the principles I have explained are embodied in this design.

Figs. 8 and 9 illustrate a project which has not yet been executed, but which, as shown in plan and section, is at least apparently based upon plausible theories. The idea is evidently to make the auditorium a spheroid in form, and I am not prepared to say that there are not reasons for supposing that it might succeed, though I am inclined to think the diminution of vertical space at the further end a mistake, in so far as it relates to the ceiling. The rising tiers, in my judgment, sufficiently reduced the space to accord with the waning force and smaller disturbance; and it is curious to note that long before the publication of this design Mr. Furgusson, the historian, had touched upon the subject of acoustics in an appendix to his "History of Modern Architecture," in which he gives a small section of what he is inclined to think the best acoustic form for an auditorium, and his section is as nearly as possible the reverse of Fig. 9.

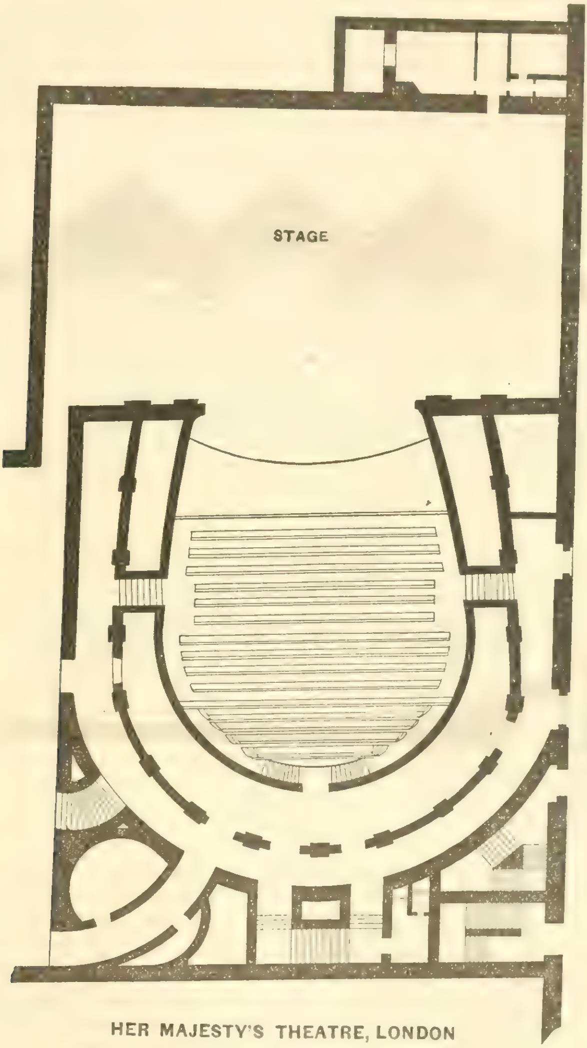
I regret that no discussion of the theories which led to the adoption of this form were published in explanation of the cuts, at least I have been unable to learn anything of such an explanation; but it is natural that a Frenchman should incline to accepting the authority of Savart, and of Lachez, rather than of Helmholtz, whose "Sensations of Tone as a Physiological Basis for the Theory of Music" is probably the most exhaustive and reliable work on acoustic phenomena extant.



TRANSVERSE SECTION
LECTURE ROOM
Fig. 3.

There are not many books that will be found important in studying this question; but in addition to the above I name a few that I have read with more or less interest. It should also, in fairness, be said, that the interest a reader finds in any particular scientific work is apt to depend largely upon the corrob-

oration of his own theories it contains. I have tried to avoid this bigotry, and have in the foregoing set down as briefly as possible what I believe to be exact and trustworthy information for practical use. If I have at times seemed to take any important step for granted, it is only because my reader would hardly care to follow a laborious technical argument, which he can construct for himself by taking the same pains that I have not spared to become thoroughly familiar with the subject, and with all that has been published concerning it, even remotely, often reading a ponderous volume merely to satisfy myself that it afforded me no assistance. The appended list is a small library, but those works marked with an asterisk will, in my opinion, sufficiently cover the subject for all theoretical or practical purposes.



HER MAJESTY'S THEATRE, LONDON

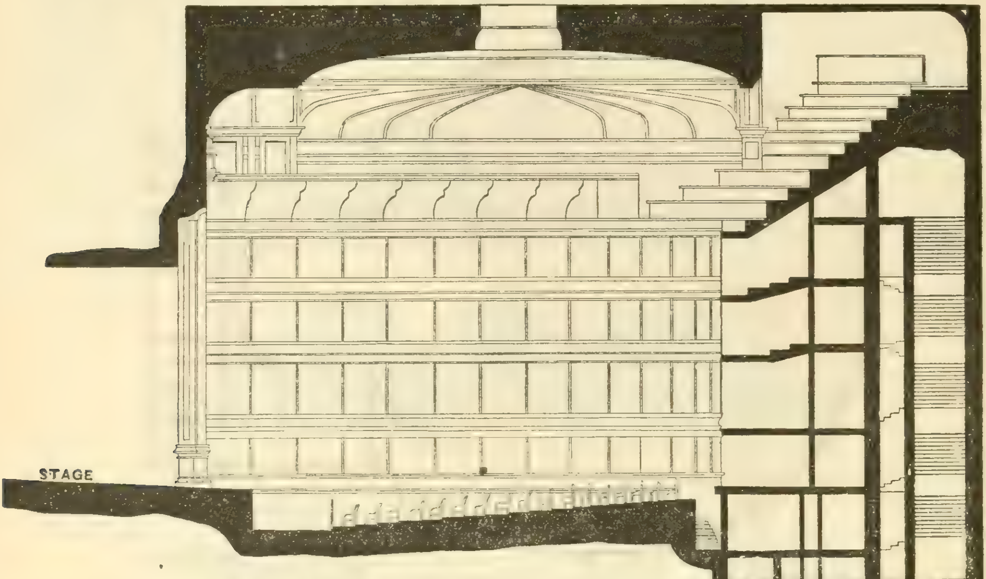
Fig. 4.

LIST OF BOOKS ON ACOUSTICS.

* "Sensations of Tone as a Physiological Basis for the Theory of Music," by Helmholtz. London translation.

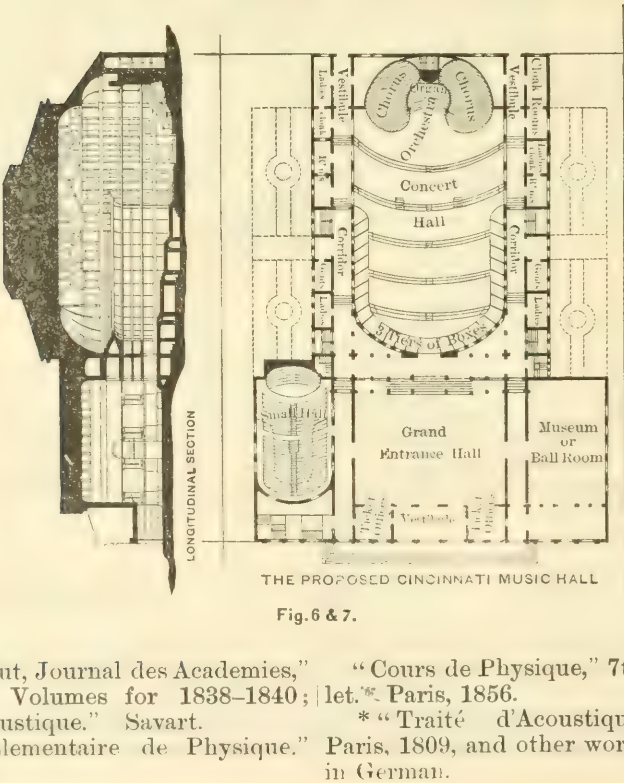
"Sound." Sir John Herschel. London, 1849.

"Memoirs de la Societé d'Arcueil." Vol. II. Biot, 1807.



HER MAJESTY'S THEATRE, HAYMARKET.

Fig.5.



THE PROPOSED CINCINNATI MUSIC HALL

Fig.6 & 7.

* "L'Institut, Journal des Academies," &c. Paris: Volumes for 1838–1840; "Cours d'Acoustique." Savart.

"Précis Elementaire de Physique." Biot. Paris.

"Cours de Physique," 7th edit. Pouillet.* Paris, 1856.

* "Traité d'Acoustique." Chladui. Paris, 1809, and other works by Chladui in German.

*Papers contributed to the "Quarterly Journal of Science, Literature, and Art," 1827–9.

*"Report on Waves." Meetings British Association, 1843–44. Scott Russel.

*"Acoustique et Optique des Salles de Réunions Publiques." Theo. Lachez. Paris, 1848.

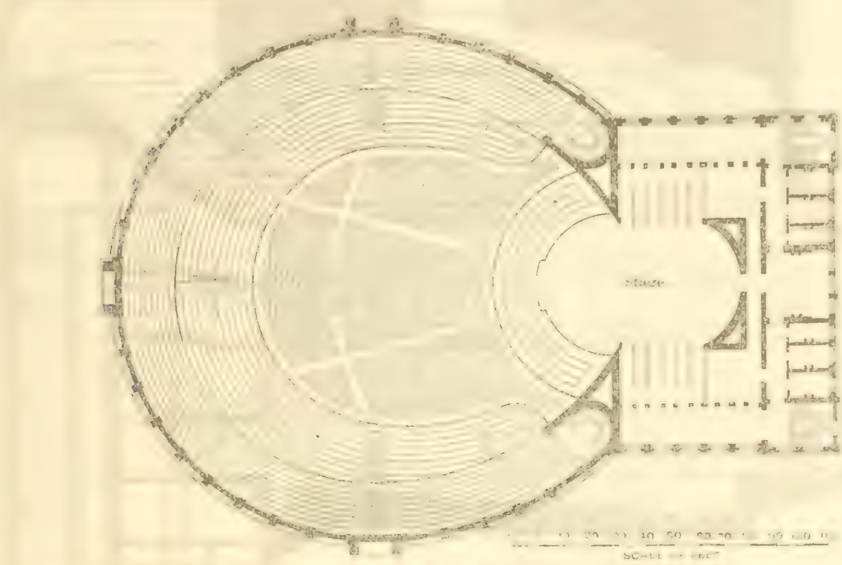


Fig. 8.

"Journal of Royal Institution," 1830–1831.

* Proceedings of Royal Institution."

*"Reports of British Association;" all at London, by Wheatstone.

"Observations on the Principles of a Design for a Theatre." Wyatt. London, 1811.

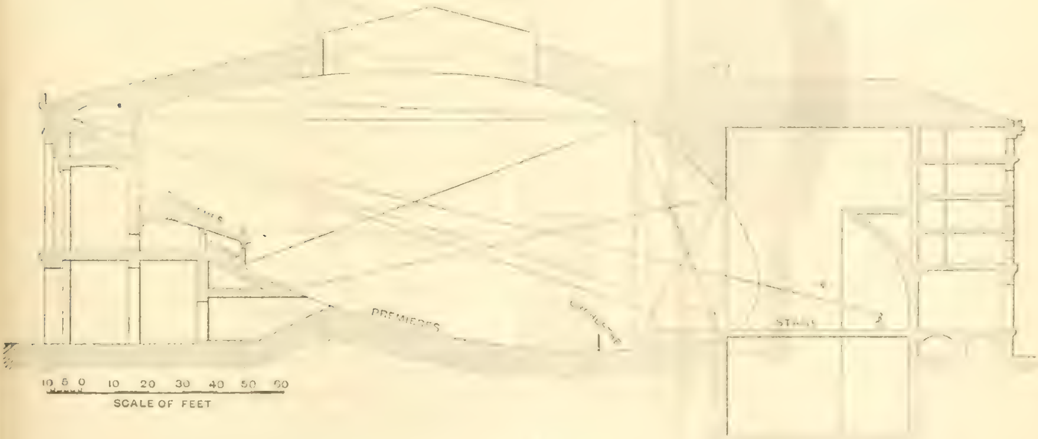


Fig. 9.

*"Annales de Chimie," &c., 1816; papers by Savart, Wertheim, Lissajoux and others.

Arnot's "Elements of Physics."

"Sound." Brewer. London, 1854.

"On the Principles of Sound and their Application to the New Houses of Parliament." Webster, 1840.

"Observations on Sound." Matthews.

*Papers read before the Royal Insti-

tution of British Architects, in February, 1847. Scott Russell. See "Builder," 1847, pages 82–118; "Building News," 1858; Nov. 26, Dec. 3–10.

* "Description of a Parabolic Sounding Board erected in Attercliff Church." Pamphlet. London, 1829, by Rev. John Blackburn, M.A.

Paper read before Architectural Associón, by T. Rodger Smith. See "Building News," Nov. 19, 1858. Another Paper by the same, before the Royal Institution British Architects, December, 1860. Printed in the "Transactions."

* "Acoustics in Relation to Architecture and Building. The Laws of Sound applied to the Arrangement of Buildings," by T. Rodger Smith. New edition. London: Virtue & Co., 26 Ivy Lane.

AN EXAMINATION INTO THE METHOD OF DETERMINING WIND PRESSURES.

By F. COLLINGWOOD, Member A. S. C. E.

Transactions of American Society of Civil Engineers.

About two years ago, the writer prepared some notes on the subject of wind pressures, which, upon consideration, he decided not to present to the society. Subsequent events have led to a modification of some of the views then held, and with these modifications they are now presented. On account of the inherent difficulties surrounding the subject, engineers have seemed to acquiesce in an empirical solution of the problem, and to decide that nothing better could be done. This is not in accordance with the spirit of investigation now extant; neither does it tend to economy or safety in construction; and it would seem that the time had come for a more thorough treatment of the matter.

In a paper by John Smeaton on the "Construction and Effect of Windmill Sails," read before the Royal Society May 31 and June 14, 1759, he gives a table of wind pressures, which have been quoted as authority in nearly all the hand and text books published since, and which is adopted by the United States Signal Service. He prefaces it thus:

"The following table, which was communicated to me by my friend Mr. Rouse, and which appears to have been constructed with great care, from a considerable number of facts and experiments, and which, having relation to the subject of this article, I here insert as he sent it to me; but at the same time must observe, that the evidence for those numbers where the velocity of the wind exceeds fifty miles in an hour, do not seem of equal authority with those of fifty miles and under. It is also to be observed that the numbers in column three (giving perpendicular force on one foot area in pounds avoirdupois) are calculated according to the square of the velocity of the wind, which, in moderate velocities, from what has been before observed will hold very nearly." (In a foot note elsewhere he explains that certain experiments by Mr. Rouse were made with windmills by a special machine constructed so as to move the wheel or sails, as a whole, through the air, and noting the weight lifted by the wheel with varying velocities of movement. The table is, therefore, apparently based on resistance by the fluid to motion through it, and *not* on impulse or pressure from the air. Whether these experiments are the ones on which the table is based is not stated, but may be inferred, although from what follows, it would seem that the table was computed largely).

Referring to Weisbach's Mechanics (Vol. I., § 390, Ed. 1848) the formula for the pressure tending to move a prismoidal body by the force of an unlimited stream of uniform velocity in which it is immersed is

$$P=(f_1+f_2)\frac{v^2}{2g}d.$$

Where P = pressure in pounds per unit of cross section.

v = velocity of stream in feet per second.

f_1 = coefficient of pressure at up stream end.

f_2 = coefficient of pressure at down stream end.

d = weight of a unit of volume of the water.

He says that where the length parallel to the axis of the stream is zero (corresponding to a thin plate) Du Buat & Duchemin found that the sum of the coefficients

(f_1+f_2) will $=1\frac{86}{100}$ or $P=1.86\frac{v^2}{64.4}d$.

For a length of

$\frac{l}{\sqrt{\text{section}}}=1$, the coefficient $=1.47$.

For a length of

$\frac{l}{\sqrt{\text{section}}}=2$, the coefficient $=1.35$.

For a length of

$\frac{l}{\sqrt{\text{section}}}=3$, the coefficient $=1.33$, &c.

And as the ratio increases the coefficient continues to diminish.

Taking the case where it equals 1.86 as being nearest to the windmill sails, and substituting 0.07925 pounds as the weight of a cubic foot of air, we have where P = pressure in lbs. avoirdupois and V = velocity in miles per hour,

$$P=0.00492\,V^2. \quad . \quad . \quad . \quad (1).$$

This equation gives results the same as those given by Rouse in the Smeaton tables.

Dubuat found that where the ratio $\frac{l}{\sqrt{\text{section}}}=o$ (or the case of a thin plate moved *against* water) the coefficient became 1.25, or the pressure is 33 per cent. less than where the water moved against the plate. This is given in article "Resistance" in Brand & Coxe's Cyclopedia as 1.43. In the same article a cylinder, with hemispherical end facing the stream is said to offer only half the resistance of the same with a plain end. Also that while the impulse of the stream against a plate 1 foot square gave the coefficient as $1\frac{9}{10}$, a plate with one-tenth of a square foot of surface gave it as only $1\frac{4}{10}$, or nearly twenty per cent. less. Hutton's theoretical deductions, as stated by Weisbach, for a sphere moving against air give the coefficient as increasing from 0.59 for a velocity of 1 meter to 1.10 for a velocity of 600 meters. In Hutton's mathematics the resistance to a spherical projectile at high velocities is given as 0.43 of that to a plain surface.

Of a hemisphere convex side forward... 40 per cent.

Of a hemisphere plane side forward.......101 per cent., &c.

In Appleton's "Cyclopedia of Applied Mechanics," 1880, is a table of pressures calculated by Mr. Alfred R. Wolff in which account is taken of the difference in density of the air at various temperatures. At a mean it differs but slightly from Smeaton's table, and would seem to be based on the same formula.

Prof. Cleveland Abbe in the article on "Wind," in Appleton's American Cyclopedia, Vol. 16, writes as follows:

"Maxwell (see proceedings of the Mathematical Society, 1870) has given theoretical formulas and curves showing the movements of particles of an incompressible fluid streaming past a moving obstacle; while Hagen (Berlin 1872), has experimentally investigated these motions. Thiesen (Wild's Repertorium, 1875) has made a careful study of the experiments of Hagen and Dohrandt, and established the rule that the pressure of the wind against an inclined rectangular plate is really very nearly proportional to the square of the velocity, and the cosine of the angle of incidence of the wind, while the absolute value of the normal pressure is as given by Hagen's observations. The latter physicist (Berlin, 1874) has embodied the results of very careful observations at moderate velocities in a formula, which converted into English measures is as follows:

$$P=(0.0028934+0.0001403p)SV^2. \; . \; (2).$$

By introducing the term (p) Hagen has expressed the fact that the pressure depends to a considerable extent on the *shape* as well as the surface of the resisting body."

In this formula P = the total pressure in pounds avoirdupois; p = the outline or perimeter of the exposed surface in feet; V = velocity in miles per hour; S = the area in square feet. The formula

applies to plain surfaces (of no considerable depth) placed normal to the incident wind, and with the density of the air corresponding to a barometric height of 29.84 inches, and a temperature of 59° Fah.

The results from equations (1) and (2), together with Smeaton's and those of Hutton, are given in the table on the following page.

All are taken for one square foot of surface. It will be seen that Hagen's are about one-third less than Smeaton's, and Hutton's about midway between the two.

The diversity of views among practical men in determining the measure of surface acted upon, the probable wind to be resisted, and how the wind acts, are well shown by the evidence given at the inquest on the Tay bridge disaster. These differences are greater even than those in the tables.

The London journal, *Engineering*, January 2, 1880, in discussing the accident, takes the lee girder as exposing one-half as much surface to the wind as the windward girder, and the whole vertical surface of the train also as acted upon; and deduces according to different supposed modes of failures pressures from $23\frac{1}{2}$ to $35\frac{6}{10}$ pounds per square foot, expressing the belief, however, that the maximum pressure did not exceed $25\frac{1}{2}$ pounds.

In subsequent numbers of *Engineering*, evidence is given as follows:

Mr. Allan Stewart placed the pressure at 75 pounds. Mr. B. Baker placed it at 15 pounds; he had experimented on glass in frames, and anything like 40 pounds per square foot would have destroyed the signal boxes. He had never seen a structure blown down which was capable of withstanding 20 pounds, and he looked upon that as the maximum pressure to be taken for structures of any kind. Fences capable of withstanding only 13 pounds had withstood storms in all situations.

He states that the French engineers assume $34\frac{6}{10}$ pounds as the greatest pressure a train can bear without overturning. One of their engineers had gone into an examination of chimneys, and had assumed an arbitrary figure of 55 pounds as the force they had to withstand, and this figure was now taken as the pressure against bridges, &c. The same has been taken by Rankine.

Mr. Baker said that in his own work he assumes 28 pounds, and varies the *factor* of *safety* with circumstances.

Dr. Pole and Mr. Stewart estimate the pressure required to overturn the bridge with no train upon it at $37\frac{4}{10}$ pounds, and with the train, at $34\frac{1}{3}$ pounds (also, $28\frac{1}{2}$ pounds as needed to overturn the lightest carriage in the open, and 33 pounds when containing eight passengers and shielded by the bridge members).

Mr. Law places the same at $36\frac{2}{3}$ and $32\frac{2}{3}$, respectively, and that 40 pounds were needed to overturn the lightest carriage in the train.

Prof. Airy states that during the gale of December 8, 1872, the greatest velocity recorded was 57 miles per hour, and he thought the pressure had reached 50 pounds per foot. The maximum pressure recorded at Greenwich was 40 pounds and then the instrument gave way.

He had estimated the pressure in the valley of the Tay at 50 to 100 pounds. "The valley runs deep, and would make a channel for the wind." He thought 120 pounds ought to be provided for, but this would allow a large margin for safety.

He did not know whether such pressures ever obtained simultaneously over so large an area as the Tay bridge. In a letter respecting the Forth bridge, he had stated "that over very limited surfaces and for very limited times the wind pressure was sometimes known to reach 40 pounds in England, and in Scotland would probably amount to more." The greatest that might be exerted over the whole extent of such a surface as the Tay bridge was 10 pounds.

Mr. Gilke, previous to the accident, read a paper in which he took the total surface exposed at about two-thirds of the amount assumed by London *Engineering*, and the pressure needed to overturn a carriage at $39\frac{2}{10}$ pounds.

Prof. Stokes, of Cambridge University, at the inquest, said he thought 10 pounds per square foot, on a plane surface, as too low. The more rapid the *fluctuations* in the wind, the less their extent laterally. As far as experiment went the pressure was found to be nearly in proportion to the area of surface. He should like to see an exhaustive series of experi-

Velocity of wind.		Pressure in pounds per square feet normal plane surface=P.						Names given to winds.		Classification by Smithsonian Institution.
				Hagen, Eq. (2).						
Feet per second.	Miles per hour=V.	Rouse, Eq. (1).	Hutton.	Circular surface.	Square surface.	Triangular surface.	Smithsonian Institution.	Smeaton—Rouse.	Smithsonian Institution.	
0.	0	0.	....	....	....	....	0.	....	Calm........	0
1.47	1	0.005	0.004	0.003	0.003	0.004	....	Hardly perceptible........	....	....
2.93	2	0.02	0.016	0.014	0.014	0.014	0.02	....	Very light breeze........	1
4.4	3	0.044	0.036	0.03	0.031	0.032	....	Just perceptible.		
5.87	4	0.079	0.065	0.054	0.055	0.057	0.08	....	Gentle breeze........	2
7.33	5	0.123	0.101	0.085	0.086	0.088	....	Gentle, pleasant, wind.		
14.67	10	0.492	0.405	0.339	0.345	0.353	....			
17.6	12	0.711	0.583	....	....	....	0.75	Pleasant, brisk, gale........	Fresh wind........	3
22.	15	1.107	0.911	0.763	0.777	0.795	....			
29.34	20	1.968	1.62	1.356	1.382	1.413	....	Very brisk.		
36.67	25	3.075	2.531	2.119	2.159	2.208	3.	....	Strong wind........	4
44.01	30	4 429	3.645	3.052	3.109	3.18	....	High winds.		
51.34	35	6.027	4.961	4.154	4.232	4.328	6.	....	High wind........	5
58.68	40	7 873	6.48	5.425	5.527	5.653	....	Very high.		
66.01	45	9.963	8.201	6 866	6.996	7.155	10.	....	Gale........	6
73.35	50	12.3	10.125	8.476	8.637	8.833	....	A storm or tempest........	....	....
88.02	60	17.715	14.58	12.208	12.437	12.719	18.	A great storm........	Strong gale........	7
110.	75	27.65	22.781	....	....	....	....	....	Violent gale........	8
117.36	80	31.49	25.92	21.701	22.11	22.613	....	A hurricane........	....	....
132.03	90	39.852	32.805	....	....	....	....	....	Hurricane........	9
146.70	100	49.2	40.5	33.908	34.546	35.332	....	A hurricane that tears up trees & carries buildings before it.	Most violent hurricane.	10

ments made on large surfaces. There were difficulties in recording velocities of the wind for short spaces of time. There is a difficulty in connecting the velocities with the pressures. Hydrostatically measured, a pressure of one pound on the square foot gave a velocity of 20 miles per hour. Experiment had shown that about 20 per cent. must be added to what is called the standard pressure (that on the surface of water in a tube), in order to get the algebraic sum of pressures per foot on both sides of a plate.

Mr. Scott, Secretary of the Scottish Meteorological office, said: "The greatest velocity registered at Glasgow (during the storm which destroyed the bridge), for any continuous 60 minutes, was 71 miles; but for one five minutes interval, it was 96 miles, for one 3 minutes interval, 120 miles, and for three others, 110 miles per hour." The storm gust at the Tay bridge was probably 300 feet wide, and some gusts may be restricted to 30 or 40 feet width.

Passing to other known disasters from wind pressure, the destruction of the Arrah road bridge across the Sone canal in India, is worthy of mention, since the weights, friction, &c., have been accurately calculated (see London *Engineering*, June 25, 1880).

This was 99 feet long, 15 feet wide, and continuous over two spans of 45 feet each. It was destroyed by a very narrow belt of wind. There were no holding down bolts, and the structure was lifted and pushed bodily off the supports, with almost no injury to the masonry.

Taking the whole vertical surface of both trusses, and the wind horizontal, and assuming the friction at 50 per cent. of weight, the pressure on the supposition of the wind striking the uncompleted span first, would be $20\frac{8}{10}$ pounds. If moved bodily, it must have been $29\frac{6}{10}$ pounds. Calcutta was the nearest point where records were kept, and during the cyclone 50 pounds were registered.

Coming nearer home, Mr. Francis, in his report on the chimneys of the Lawrence Manufacturing Company (published in *Engineering News*, Aug. 28, 1880), states the highest recorded pressure for fifty years past on the New England coast to be 50 pounds.

Mr. C. Shaler Smith, in his paper before this society of December 15, 1880, states pressures in the Western States at from 18 to 93 pounds, but does not state how the results were arrived at.

Mr. W. Hartnell, in a discussion in *London Engineering*, of January 2, 1880, states, respecting the gale in 1868, during which a momentary pressure of 80 pounds was recorded at the Bidston Observatory in Liverpool, that on the side of the observatory farthest from the sea, the pressure was only 38 pounds. He says further, that behind a flat plate a *partial vacuum* is formed by wind rushing past the edges. One per cent. of vacuum would give an increase of pressure per foot of 21 pounds. He says that narrow, flat bars, and open structures generally, offer a *maximum* resistance per foot of area. So that a statement of so much pressure means nothing, unless we know just how it is taken. He also says that a squall in still air will travel, say 20 miles per hour, and will blow at 30 miles for a short time, thus "exerting twice the pressure that might have been expected." In other words, that the maximum pressure is twice that due to the average velocity of the wind.

It is not necessary to go farther to illustrate the conflict of opinion which surrounds every branch of this subject.

There can be no doubt that much of the uncertainty arises from the use of imperfect apparatus, the *inertia* of the parts being entirely overlooked. On this point the article "Anemometer," in the *Cyclopedia Britannica*, although written some years ago, is, in a measure, true now. It says: "If the currents of air were anything like uniform, it would be a comparatively simple matter to deduce the velocity from the pressure; but their variability is so great that the relations between them become unworkably complex. We know from the elementary principles of dynamics that the pressure at any instant will vary as the square of the velocity. Obviously, therefore, the relative variations of the pressure will be *twice* as great as those of the velocity; and the *latter* are too great, as we find them to encourage us to double them artificially. It must be remembered also, that from the *inertia* of the indicating apparatus, errors will in every case arise, and *these* also will be doubled if we take the pressure instead of the velocity indications. From all this it will appear that comparatively little importance is to be

attached to the earlier, and to *all* statistical anemometry."

As an example of the apparatus used for recording pressures, may be instanced that at the Central Park in New York, as described in the report for the year ending December 31, 1869. A storm occurred December 18, 1869, which is fully recorded in the same report. The apparatus consists of a hollow metal cylinder 2 feet high and 1 foot diameter, suspended with its axis vertical by a chain, and having a chain extending from its lower end, and connecting with a spring balance. As the wind blows the cylinder to one side, the spring is extended, and a pencil attached to the spring is moved up, and records its excursion on a sheet of paper traveled slowly past it by clock work. By testing the power required to extend the spring to various points, it would seem that a fair measure of the pressure might be obtained.

On examining the record of the storm mentioned, however, it is seen to be a series of quick strokes outward, and back again nearly to the zero line. So much is this the case, that the paper is shaded almost black near the zero line, becoming lighter as we pass from it, and with a few detached strokes of no appreciable duration at the extreme pressure. The *greatest* pressure recorded is 22 pounds, and that only twice, and at long intervals. Of 18 pounds pressure or over, there were four at intervals of 12½, 30 and 35 minutes respectively. At 15 pounds and over, about 10, with intervals of 2½ to 30 minutes. These are approximations, as it is difficult to measure from the lithograph.

It is evident that these records are vitiated by the *inertia* of the cylinder, just as when a pound weight is suddenly placed upon a spring balance, about 2 pounds will be momentarily indicated.

The instrument can in no case, however, be considered a scientific one, and there seems to be a similar difficulty with most of those employed.

Another source of error is well pointed out by Mr. Ashbel Welch, in his paper before the Society, of May 25, 1880.

If we take the fundamental formula $h=\frac{v^2}{2g}$ and calculate the pressures corresponding to air at the standing temperature and density, the results given will be very closely one-half only of those given by Rouse and Smeaton. We know, however, that the actual pressures from the wind are greater. Could each particle of air give up all its motion, and get out of the way of those to follow without affecting the latter, the result would be rigorously true. There is, however, a piling up or condensation at the front or incident surface and a lateral flow—such, that the stream to be considered has virtually a larger section or base than the surface acted upon. In addition, there is the partial vacuum in the rear, noted by Mr. Hartnell, but first pointed out by some of the earlier experimenters on the subject.

These results, as we have seen, are modified not only by the shape of the incident surface, but also very largely by the length of the body acted upon in the direction of the wind current.

To sum up from the data given, we find the following sources of error, if we consider the maximum pressure of the wind, upon the exposed surface of a structure, as required by the engineer in proportioning its parts:

1st. Imperfect anemometers, vitiating results by the inertia of the moving parts, thus tending to make results too large.

2d. The difficulty of translating velocities into pressure, tending to make results too *small*, since the velocity recorded is an average over a period of time, and not that at the instant of greatest pressure.

3d. The data on record are not exact. To serve the purposes of science every circumstance as to size of parts, character and shape of surface, size of openings, height above ground, and location, must be noted.

4th. Almost all the records are based upon the assumption of a horizontal wind, whereas all experience shows that this is incorrect, and that the largest possible projection is liable to be the one acted upon.

In reference to height above ground, and direction of wind, the following memoranda are to the point.

In *Engineering News*, of September 11, 1880, is an article referring to experiments with a specially devised anemometer, by Mr. S. Fraser, of the Scottish Meteorological Society. He says that

wind currents are much modified by the ground over which they pass. For example, in front of the Royal Observatory in Edinburgh, their deflection from the horizontal was about 45°. On the level ground it was not over 15°, except in one case near Edinburgh, when it suddenly assumed nearly a *vertical* position. In the case already mentioned of the Arrah road bridge, it would seem that there was a strong lifting, as well as a horizontal force, to have removed the bridge with so little damage to the masonry.

As to the effect of height there is in the monthly weather report of the U. S. Signal Service for September, 1880, the following quotation from a "Report on Results of Wind Observations, made with small cup and dial anemometers at different heights, by Thomas Stephenson, M. I. C. E., published in the Journal of the Scottish Meteorological Society:

"Although additional observations are much wanted at high levels, the results, so far as appears from the observations on winds varying from 2 miles an hour to 44 miles an hour, show:

1st. That spaces passed over in the same period of time by the wind increase with the height above the sea level, or above the surface of the ground.

2d. The curves traced out by those variations of velocity (from 15 feet to 50 feet above the surface of the ground, and possibly higher) coincide most nearly with parabolas having their vertices in a horizontal line 72 feet below the surface.

3d. Between 15 feet and the ground surface there is great disturbance of the currents, so that the symmetry of the curves is destroyed.

4th. The parameters of these parabolas increase directly in the ratio of the squares of the velocities of the different gales:—if x be taken as the velocity of the wind at H feet above the ground the parameter of the corresponding parabola is $\left(\frac{x^2}{H+72}\right)$ and as x varies, the parameter will vary as x^2, or as the square of the velocity of the gale.

5th. In order to render wind observations comparable, all anemometers should, if possible, be placed at a uniform height above the ground, and that standard height should not be lower than 20 feet above its surface, but, were it generally practicable, 50 feet, or a still greater height, would be better.

6th. When it is desired to find for *small heights* the velocity V at any point H feet above the ground, from the known velocity v at a height h feet above the ground (h being *above* 15 feet), the formula is $V=v\sqrt{\frac{H+72}{h+72}}$; when H is above 50 feet above ground, the V got from the formula is slightly in excess of the actual velocity. When it is wanted to ascertain the velocity for *great heights* above the sea level, the approximately correct formula, which is believed to be sufficiently correct for practical purposes, is $V=v\frac{H}{h}$.

7th. It would be well for meteorologists to adopt this reduction formula and to express all wind velocities as referred to the height of 50 feet above the ground. This formula in this case becomes

$$V=v\sqrt{\frac{122}{h\times 72}}."$$

It is no wonder after what has been given, that engineers disagree as to the pressure of wind even in a given case. We find one man taking the vertical projection of one truss, another of one and a half, another of two, and so on, and almost no reference made to any other portion of the structure or to any differnet projection.

Again the same pressure is taken for a bridge in a clear, open space, or for a gorge where, as Mr. Cooper (Vol. IX—394 of "Transactions") has pointed out—there may be developed "local currents of much greater velocity," than the average of the storm.

Again, the same pressure is ordinarily taken for a short bridge, as for a long one, and we have a common agreement, among observers that the violence of storms is exerted over only limited areas, and is progressive in its character. There is also the other fact, that for structures of great span, the danger from repeated or "rhythmic" gusts (spoken of by Mr. Cooper) is exceedingly small. An examination of the storm record, given in the Central Park report, will show that the

gusts are hardly such as to cause this danger to structures whose period of vibration is very slow.

The experiments and observations needed to secure a scientific treatment of the whole subject, and uniformity of practice among engineers, must be more exhaustive than any heretofore made; but we shall never reach the desired end by assuming that it is unreachable. In the hope that this review may assist in promoting a movement in the right direction, this paper is respectfully submitted.

THE PRESENT STATE OF THE WATER SUPPLY AND SEWAGE QUESTIONS.

Abstracts of Papers of the Chemical Society and the Sanitary Institute of Great Britain.

A PAPER on "River Water," by Dr. Meymott Tidy, before the Chemical Society, was mostly a reiteration of the principles advocated in a former communication, in reply to Dr. Frankland. The discussion relates to the agencies to which the self-purification of running water is due; whether subsidence, the scavenging propensities of fish, or the oxidation effected by the atmosphere and plant life jointly.

First, as to the oxidation of peat, notwithstanding Dr. Frankland's objections, the author still maintains that the Shannon is admirably adapted to prove oxidation, should such a process be going on, admit the ever recurring entrance of feeders of peaty water if it can be shown that in spite of this constant addition of peaty matter there is a manifest lessening of the peat in the water, then the experiment, considering that all the chances and conditions are against proving oxidation, becomes a hundredfold more conclusive than it would otherwise be. Admitting that at four points along a course of forty miles at Portumna, Killaloe, O'Briensbridge, and at the junction of the Mulcaire the organic elements do indicate a fairly uniform quantity of peat in the water, the question remains, what has become of the floods of peaty matter which have entered the river during its forty-mile flow? Why does not the peat in the river increase in quantity yard by yard? Starting with a brown water at Killaloe, the river should be black over and over again before it reached Limerick. The author sums up this part of his paper thus: "I cannot question for a moment that peat is got rid of in the course of the flow of a river, and that oxidation is one of the agencies concerned in its accomplishment." He then criticises the paper by Miss Halcrow and Dr. Frankland on the action of air on peaty water, and objects that in no sense are these experiments, in which the same dribble of water is brought ever and anon into contact with the same few bubbles of air, comparable to the case of the Shannon, a river of great volume, in free and open contact with an ever-changing sea of air, luxuriant with vegetable life and fish. In one series of experiments in which some peaty water was allowed to remain for a year in contact with some air in a stoppered bottle, the author objects that, admitting oxidation to have occurred at the layer where actual contact took place between the water and air, any carbonic acid formed would act as a party wall to divide the water from the purer air above, and, making all allowances for diffusion, there practically would be an end of the process. He also points out that the carbonic acid was in enormous excess in the air above the water, viz., 14.7 parts in 10,000. Dr. Frankland's experiments on the Irwell, the Mersey, and the Darwen are next considered. "These are," says the author, "notoriously polluted sewage rivers, containing no vegetation, devoid of fish, and everything was against the regaining of purity," yet Dr. Frankland's results show, in the case of the Darwen, a decrease of organic elements of 41 per cent., and in the Irwell of 31 per cent. Again, in the case of the Tees, a river polluted at Barnard Castle by the sewage and refuse from dyers and fellmongers, after a flow of sixteen miles this river is reported at Darlington, by Dr. Frankland, as of unimpeachable quality, bright and palata-

ble. As Dr. Frankland's statements, that in the Severn a flow of thirty yards reduces the organic elements by 32 per cent.. and that after a flow of a mile they were only reduced 12 per cent. more, the author contends that sewage is not of a constant composition, and that some constituents are much more easily oxidized than others. As regards the wonderful diminution of chlorine remarked by Dr. Frankland, the author still maintains that it was taken up by vegetation, and quotes an experiment in which he watered some watercress with a solution containing 40 grains of salt per gallon, and increased the quantity of chlorides by 220 per cent. He gave the statistics of ten years, which prove that zymotic diseases do not necessarily result—sewage or no sewage—from drinking river water, any more than they can be kept away by drinking chalk water. He asks Professor Huxley this question: Can you give one single well-authenticated case where a drinking water, in which the chemist failed to detect manifest contamination, has caused disease? The author concludes by asking Dr. Frankland, as the dangerous element in a water is entirely outside his ken or detection, what in his judgment is the good of water analysis? Seeing that 100,000 bacteria may be present in a gallon of water, each bacterium being capable of imparting disease, and yet be undetected by the most refined chemical processes, how can he report any water to be wholesome? What are his grounds for reporting a water containing 0.1 of organic carbon to be of good quality, and a water containing 0.4 of organic carbon to be of inferior quality, seeing that the first named contained millions of bacteria, which may be entirely absent from the second? Why should absolute immunity from epidemics of cholera be promised, if only London would drink chalk water—which after all is merely rain water, and must have fallen in certain parts on heavily manured land, and has afterwards filtered naturally through chalk—and yet it be stated that there is not a tittle of trustworthy evidence to prove that artificial filtration—which, judging from analyses, is more complete than natural filtration—affords any safeguard against the propagation of epidemic diseases?

Dr. Frankland said that it would be difficult to notice at that late hour all the salient points of Professor Tidy's elaborate paper, but he would endeavor to refer to some of them. Professor Tidy has explained that the purification of rivers is effected by three processes—subsidence, the action of fish life, and oxidation. As regards the second, he does not clearly state whether the fish remove organic matters in suspension or in solution. Fishes of respiration must clearly remove oxygen from the water; so it would seem that they could only remove organic matter in suspension. However, the substantial difference of opinion was on the question of oxidation, to which he would therefore confine his remarks. He would have liked to have said something about the admirable paper by Mr. Hatton, but as time pressed, he must leave the results to speak for themselves. First, as to the oxidation of peat in the Shannon, Professor Tidy states that in a flow of one mile from Killaloe the organic carbon decreases from .8 to .48. This really means that half of the total organic matter has been converted into carbonic anhydride, water, and ntirogen, or ammonia, in the flow of one mile. He would ask any chemist who has been accustomed to organic compounds whether he is acquainted with any substance which behaves in this way. To take one instance—aldehyde—a substance most prone to decomposition, it, under similar circumstances, would hardly be oxidized perceptibly. How improbable is it that the flow of a mile should cause such an enormous reduction, whilst the exposure of fifty-one square miles of surface in the loch above should have such a slight influence! Does Professor Tidy really think that this entrance of feeders of peaty water has any very great influence on the composition of the Shannon, a river which drains about a quarter of Ireland? None of these feeders have a flow of more than a mile, and so they cannot be insignificant. He must take exception to two of the three new analyses which Professor Tidy gives, namely, those taken one mile below Castle Connell and at Limerick. Now, the entrance of the largest tributary—the Mulcaire—a river containing but little organic carbon and much suspended mineral matter, which,

in its deposition, carries with it much organic matter—completely prevents any fair comparison between these two places. Notwithstanding Prof. Tidy's great faith in nature, and his objection to any experiments in a bottle, the speaker ventured to say that in the case of the bottle, which was fastened to the connecting rod of the steam engine, the water was brought into contact with air much more perfectly than in nature, and yet no oxidation could be detected.

The discussion of the sewage question, before the Sanitary Institute, has been revived by an address by Prof. W. H. Corfield, of which the following is a brief report:

That the removal of refuse matters was a highly important matter for consideration was very evident, the lecturer thought, from the fact that wherever a district had a slow system of removal or none at all, the death rate was very high, and just in proportion as the removal was expedited the number of deaths and cases of enteric disease decreased. The results of the non-removal of refuse matters was shown by the spread of black death, Oriental plague, cholera and enteric fever. The entire depopulation of many ancient cities was, he believed, due to the injurious effects of the accumulation of filth. Having pointed out that utilization, though no doubt important, was a secondary matter, and indeed was what an athlete would call "a very bad second," the reader of the paper proceeded to consider the systems of sewage removal and treatment at present in use under the two heads of conservancy systems and water carriage. In the former—which might have been so named by their bitterest opponents, instead of the title being one adopted by their advocates, as the very object of the sanitarian was "removal," not "conservation"—the refuse matters were either collected unmixed with anything else, or mixed with ashes, earth, &c. The first of these plans was now being adopted in several large towns, as Birmingham, Rochdale, &c., and it might be said to be the only successful one among the conservancy systems. It was certainly the only one from which a profit had been obtained; the manure in all the other plans was nearly valueless, and the results obtained by the Sewage Committee of the British Association showed that the earth compost, after having been used in the closets six times, was only as rich as a good garden soil, and would not bear the cost of carriage. The total manurial value of human excreta had been estimated at 7s. 3d. per year for the liquid refuse, and 1s. 3d. per year for solids, but all chemical analyses of manures placed their value at a higher rate by about one-half than they possessed to a farmer. A summary was given of the results obtained by the conservancy systems, in which they were shown not to be solutions of the questions, especially as they leave the liquid sewage still to be treated, but in which it was admitted that under certain circumstances as where it was necessary to reduce the bulk of the sewage, they might with proper precautions be adopted. The recent improvements had been in the direction of reducing the size of the receptacles, so that they had to be removed at shorter intervals, in making them water tight and in ventilating them. The interest of a local authority, and still more of its contractors, was to empty the pails as seldom as possible—a radically bad principle. The water-carriage system was considered somewhat in detail; its advantages in the continuous removal of refuse from houses pointed out, its disadvantages shown not to be inherent in the system, but to the mistakes made in carrying it out, as for instance, sewers pervious to water, or too large, or not ventilated, or without sufficient fall, or with a blocked outlet, or discharging into rivers, house draining not properly disconnected. The folly of turning surface water, and, in many instances, even springs and streams into sewers, and so increasing the difficulty of dealing with the sewage at the outfall was insisted on. The various chemical processes for the treatment of sewage were passed in review, and all shown to be quite inadequate to cope with the difficulty, though some might be useful as preliminary aids to purification. Filtration through soil and wide irrigation were next treated at some length, and the results obtained by them described. Certainly the sewage had been satisfactorily purified in many cases, the conditions

for satisfactory purification in winter being that the sewage pass through the soil and not merely over it. Crops of all kinds had been grown by means of it, and in soil that would otherwise bear nothing; and the British Association's Sewage Committee had shown at Britton's farm, Romford, during five years' daily investigation and analysis, that as great a percentage of the manurial constituents, 33 per cent., of nitrogenous compounds had been utilized as was on an average utilized of the best commercial manure. Although, for various reasons, it had seldom been found to be remunerative, the reader adhered to his opinion, formulated ten years ago, that sewage irrigation would ultimately be remunerative in many instances, and that opinion was shared by the committee appointed by the Local Government Board in 1876 to inquire into modes of treating town sewage. An irrigation farm should be supplemented by a filter bed to receive and purify sewage when it is not wanted on the farm. The supposed dangers from the proximity of such farms, or from the spread of entozoic disease, were found to be purely imaginary; it was on the whole a better solution of the question for a large number of places than any other, and if, as was very likely, we had a series of dry years, its adoption would receive a great impulse. Where towns could not make sewage utilization pay, they must be content to be taxed to a slight extent to get rid of a most serious nuisance, and to secure a low death rate.

A short discussion followed, in which Messrs. Sillar advocated the Aylesbury precipitation process, in which he was he said, pecuniarily interested; Mr. Douglas Onslow, managing director of the Coventry sewage purification works, defended the operations there carried out; Mr. Bailey Denton, Jr., spoke of the intermittent downward filtration works carried out for many years past by his father; Mr. R. W. P. Birch agreed with the lecturer, that no fine line should be drawn between irrigation and intermittent filtration, but that on the sewage farm both plans should be adopted as the season demanded; Mr. Jeumain described Lord Warwick's sewage farm at Leamington, and asserted that sludge had a manurial value; and Mr. Thomas Wilson Grindle suggested that as Hillé's system, which he was carrying out at Edmonton, was practically the same as the Aylesbury and Coventry processes, a conference should be convened to arrive at an amalgamation of the several sewage companies.

The Chairman said this was attempted at the Leamington congress 16 years since without any result. A long experience in the working of the Croydon sewage farm, which was situated in a somewhat densely populated area, had shown him that this was the best means of sewage disposal, and that it was absolutely no nuisance or danger to the neighborhood. Forty tons of vegetables could exhaust the manurial qualities imparted to land by irrigation with 5,000 tons of sewage, so that its fertilizing properties had been overrated. The practical difficulty was to get an intelligent farmer to occupy such a farm under so changing and occasionally so arbitrary and ill-informed a body as a "local authority."

Dr. Corfield replied upon the discussion, ridiculing the notion that any plan of "fortifying" sewage could pay. Doubtless sand could be made to pay for carriage and treatment if gold dust were sprinkled over it; but no one would assert that the enrichment with gold dust, to be subsequently extracted was a remunerative or wise enterprise. The simile held good with all additions to sewage; the stuff itself was worth, on a favorable computation, about 2d. per ton, and the cheapest chemicals that could be added to it would not make the compound worth carriage, plus their original cost to the farmer. A vote of thanks was passed to the lecturer on the motion of Mr. Rogers Field and Professor Symons.

THE Municipal Council of Paris has recently made a great improvement in the arrangements of the Morgue, by adopting the refrigerating apparatus of M. Mignon and Rouart at a cost of 53,000f, The bodies on view will thus be enabled to be preserved for any length of time within reason, and the sanitary conditions of the Morgue will be greatly altered for the better, while the longer period of exposure will frequently further the ends of justice and give more frequent opportunities for identification.

ON CERTAIN REACTIONS IN THE BASIC CONVERTERS.*

By M. POURCEL.

From "Iron."

The experiments, the result of which I gave at the last meetings of the society, prove that the phosphate of lime when tribasic, and even when it contains more than three equivalents of lime, is, in the absence of every trace of silica, decomposed partially by the manganiferous pig (or otherwise) which absorbs the phosphorus. I had then, and, I admit, erroneously, expressed an opinion contrary to that of Mr. Rollet. Mr. Rollet's opinion is, that a silico-phosphate of an alkaline earth, sufficiently basic, does not yield any of its phosphorus to pig iron melted in contact with it; but if the silico-phosphate contains phosphate of iron in admixture, the latter is reduced by the pig, which completely absorbs the phosphorus.

The following experiments tend to verify these two facts:

(1) A kilogramme of white pig iron containing .06 per cent. of phosphorus was melted in a plumbago crucible, lined with a brasque of calcined dolomite, with 225 grammes of slag specially prepared of the following composition:

	Per cent.
SiO_2	15.00
Ph_2O_5	9.40
CaO	58.75
MgO	10.62
$Al2O_3$ and a little Fe and Mn	5.50
S	0.73
	100.00

The fusion occupied two hours. The button of iron run into a mould weighed 997 grammes; it contained 0.101 per cent. phosphorus. The accompanying slag contained 14.30 per cent. silica, and 10.44 per cent. phosphoric acid. Consequently the pig, notwithstanding its prolonged contact with the silico-phosphate, had absorbed scarcely any phosphorus. If, as is the case in making the final additions in the basic converter, the contact with the slag had been of short duration, the absorption of phosphorus would have been "nil."

(2) The same experiment was repeated in a plumbago crucible, brasqued with vegetable charcoal as free from ash as possible. The slag had been made so as to contain the same quantity of phosphoric acid, but about 20 per cent. of silica. The fusion occupied the same time as in the preceding experiment. The button of iron could not be weighed. Its fracture was that of a fine-grained grey pig. The phosphorus was 0.105 per cent., and the accompanying slag contained 21 per cent. of silica. Consequently, even with a slag containing 21 per cent. of silica, and 10 to 11 per cent. of phosphoric acid, the absorption of phosphorus is inappreciable.

(3) In a plumbago crucible, brasqued with vegetable charcoal, a kilogramme of the same white pig iron containing 0.06 per cent. of phosphorus was melted with a mixture of 112 kilogrammes of the slag used in the first experiment, and 41 grammes of phosphate of iron, containing in round numbers 15.5 grammes of phosphoric acid, and 25.5 grammes of oxide of iron. Reduced to percentages this slag was composed as follows:

	Per cent.
SiO_2	10.90
Ph_2O_5	17.30†
CaO	43.00
MgO	7.80
Al^2O_3, &c.	4.00
Fe_2O_3	17.00
	100.00

Fusion was completed in about two hours. The button of metal run into a mould weighed 1024 grammes; it presented a close-grained dark fracture. The percentage of phosphorus was 0.64 per cent. If all the phosphate of iron had been reduced to phosphide and incorporated with the pig, supposing there were no loss of iron whatever, the theoretical content would have been 0.68 per cent. This result at first surprised me, and I can only explain it from the manner in which the experiment was con-

* A communication addressed to the Société de la Industrie Minérale.

† 7.15 per cent. combined with the silico-phosphate. 10.15 per cent. combined with the oxide of iron.

ducted. The phosphate of iron in a powdered state was placed in the bottom of the crucible in contact with the reducing brasque, and covered by the silico-phosphate in lumps—possibly the reduction of the phosphate to phosphide was effected before the complete fusion of the silico-phosphate; this may explain its almost total incorporation with the pig.

Generally when a silico-phosphate is not saturated, the phosphate of iron melted in contact with it is partially decomposed, oxide of iron is set free, and the phosphoric acid passes into the silico-phosphate. Such is the reaction that takes place in the basic converter during the overblow in the presence of an excess of lime. When, however, the lime is not in excess, the slag may contain the greater part of the phosphoric acid as phosphate of iron, and the re-integration of the phosphorus in the bath of refined metal becomes more apparent when the spiegel is added.

Such was the case at the first experiments of the Thomas Gilchrist process at Eston.

I myself came to the conclusion after making some laboratory experiments—which, however, were not sufficiently conclusive—on slag produced at the Eston works, that the whole of the phosphorus in the slag existed as a phosphate of iron; but this I acknowledge was an error. The experiments which I have just described may, I think, be summed up as follows:

(1) That a slag containing from 15 to 20 per cent. of silicon, and 10 per cent. of phosphoric acid, will not part with an appreciable quantity of its phosphorus on the addition of the spiegel.

(2) That this re-integration of the phosphorus is proportional to the quantity of phosphate of iron dissolved in the slag, a silico-phosphate of fixed and definite composition; and then proportional to the weight of the spiegel added at the end of the blow. These views are, I believe, not at variance with those of Mr. Rollet. The hypothesis of Dr. Wedding, admitted by many German professors, that the manganese of the spiegeleisen is the reducing agent of the phosphoric acid, incorporated in the slag as phosphate of lime, does not then appear to be justified. We are not here dealing with a phosphate of lime; but, as I observed in my first communication on the Thomas-Gilchrist process in June 1879, with a silico-phosphate with an excess of base, which does not give up its phosphorus.

It may be asked whether phosphate of lime dissolved in fluor spar would not be altered by fusion in contact with pig iron. My belief is that it would be, and an experiment in confirmation of this would not be without interest. I had ample proof from an experiment made in September, 1879, that it was possible to eliminate simultaneously carbon and phosphorus from pig iron, by means of fluor spar and an oxidizing agent. The experiment I then made was as follows: 180 grammes of a fusible basic compound formed of 100 grammes of pure lime and 80 grammes of fluor spar were melted in a plumbago crucible, with 100 grammes of a pig, containing 17 per cent. of phosphorus and about 1.25 per cent. of carbon estimated by difference, and 200 grammes of oxide of iron ($Fe2O_3$) precipitated, containing 62 per cent. of iron, and 3.40 per cent. of water. This mixture was calculated to furnish sufficient oxygen to burn the carbon, and oxidize the phosphorus of the pig, in order to form a very basic phosphate of lime. A button of metal was obtained, weighing 196 grammes. The fracture was that of a crystalline soft steel. It forged very easily, and contained

Iron	99.146
Carbon	.467
Phosphorus	.380
	99.993

There was a considerable quantity of slag, which contained some shots of white metal. It was white, and yielded on analysis, 1.90 per cent. of iron and 3.463 of phosphorus; the weight of the well melted, but somewhat honey-combed part, was 461 grammes. This considerable weight is attributable to the melting of the dolomite brasque of the crucible.

In the numerous experiments that I have made in crucibles of this class, the graphitic lining alone is damaged, whilst the dolomite part remains hard, free from cracks, and, placed in a new graphite crucible, may serve for a great many experiments. But, in the presence of fluor

spar, the dolomite brasque is always strongly attacked, and if, instead of melting together the mixture of lime and fluor spar in a carbon medium, the fluor spar be put separately in the crucible to be used in the experiment, the crucible is generally eaten through before complete fusion has been effected of the various substances mixed together. In the experiment just described, even if an exact debtor and creditor account of the materials charged, and the product, cannot be given, still the balance sufficiently approximates to the truth, to prove that the phosphorus of the pig iron attracted by its affinity for *lime in fusion*, acted in preference to the carbon as the reducer of the oxide of iron. The latter was almost completely reduced, since the slag contained but 1.90 per cent. in the state of oxide, or rather less than 9 grammes in all. As regards the carbon of the phosphoric pig—and this is the principal fact in the experiment—it was found to remain in a great measure in the metal. Of the 1.25 grammes contained in the pig charged, we have in the product $196 \times .467 = .915$ grammes.

I communicated the result of this experiment to some of my friends at the time, but I had reasons for not publishing the details. Referring to the *Compte Rendu* of the meeting of October 4, 1879, page 227, I there, in answer to Mr. Laur, contented myself by replying in the following terms: "The chlorides of iron are volatile, in fact, extremely so. My conviction is, contrary to that of Mr. Laur, that apatite is not likely to be formed; under the action of the iron, chloride of calcium will yield thick fumes of volatilized chloride of iron, with fluoride of calcium. There will also be a loss of iron in the state of fluoride; but the principal reaction to be feared is the eating away of the sides and bottom of the vessel."

I could not deny the action of fluor spar, of which I was already aware; I merely mentioned the trouble to which its use was likely to give rise. If the experiments which Mr. Harmet related as having been carried out at Bochum, have not been repeated since last November, it is probably due to difficulties existing beyond the cooling of the bath of metal from the heat absorbed by the dissolution of the lime in the fluor spar, and the formation of volatile compounds. The desulphurizing influence of fluor spar, or of lime dissolved in borax, in a reducing medium, was the subject of a note I presented to the Société de l'Industrie Minérale, August 5th, 1876. The conclusion at which I then arrived, was that lime, under whatever form it may be introduced into a slag, retains the sulphur as a sulphide of calcium, when the temperature is high enough to permit the fusion of a basic slag.

OBITUARY.—Died, on the 14th of July, at Rio Janeiro, Col. W. Milnor Roberts, past President of the American Society of Engineers, and late Chief Engineer of the Public Works of Brazil.

From a history of his professional career, recently published in the columns of the *Engineering News*, we take the following sketch:

"Col. Roberts was born in Philadelphia, Feb. 12, 1810. His aptitude for mathematics early introduced him to the then new profession of civil engineering, and in the spring of 1825 he received his first appointment as a chainman of the Union Canal, of which Canvass White was Chief Engineer, and Sylvester Welch, Locating Engineer. At 18 years of age he was appointed engineer in charge of the most difficult division of the Lehigh Canal, from Mauch Chunk down, sixteen miles, and from that time forward he was always intimately connected with great canal and railway enterprises, principally in Pennsylvania and New York States, with intervals in Brazil, and in the Western States. He held important offices under the United States Government, was Chief Engineer of the Northern Pacific Railway, Associate Chief Engineer of the St. Louis Bridge, and an active and important member of the Mississippi Jetty Commission. In 1879, shortly previous to his departure for Brazil, Col. Roberts was elected President of the American Society of Civil Engineers, a society of which he was a very active and always interested member, and which will very keenly feel his loss. Though so far advanced in years, Col. Roberts was an unusually active and energetic man, and some idea of the extent and difficulty of his labors in Brazil may be gathered from letters which have been

published in this journal during the past two years. Col. Roberts was possessed of a most genial and kindly disposition, and the news of his death will be received with feelings of great sorrow by the entire profession of which he was a member, as well as by a very large list of friends in this and other countries where he was known.

REPORTS OF ENGINEERING SOCIETIES.

American Society of Civil Engineers. The last No. of the Transactions contains the following papers:

No. 220. "Wind Pressure upon Bridges," by C Shaler Smith.

No. 221. "An Examination into the Method of Determining Wind Pressure," by F. Collingwood.

The discussions upon these two papers, which also appear in the present issue, express the views of several prominent members, and contribute to make this an exceedingly valuable number.

Cleveland Engineers' Club.—The July meeting of the Engineers' Club was held on the evening of the 6th, with Colonel J. M. Wilson in the chair and a large number of members in attendance. The following papers were presented:

Paper—"Remarks on George Stephenson," by A. Mordecai.

"Buildings in the City, Public and Private," by J. M. Richardson.

"Connotton Valley Railroad—Its Progress, Lines and Bridges in the City," by H. F. Dunham.

"Results of the Annual Meeting of the American Society of Civil Engineers at Montreal, in June, 1881," by Charles Latimer.

"Candle Power of light—How Determined," with experiments, by G. A. Hyde.

"Recent Break in Case Avenue Main Sewer —Cause, Heavy Land Slide," by B. F. Morse.

No meeting held in the month of August.

The Institution of Civil Engineers — The originality, labor and ingenuity displayed by the authors of some of the communications submitted to this Society during the past Session, have led the Council to make the following awards:

FOR PAPERS READ AT THE ORDINARY MEETINGS.

1. George Stephenson Medals, and Telford Premiums, to Thomas Forster Brown and George Frederick Adams, MM.Inst.C.E. for their paper on "Deep Winning of Coal in South Wales."

2. A Watt Medal and a Telford Premium, to John Isaac Thornycroft, M.Inst.C.E., for his paper on "Torpedo Boats and Light Yachts for High Speed Steam Navigation."

3. A Telford Medal and a Telford Premium to Theophilus Seyrig, M.Inst.C.E., for his paper on "Different Modes of Erecting Iron Bridges."

4. A Telford Medal and a Telford Premium to Max am Ende, Asso.M.Inst.C.E., for his paper on "The Weight and Limiting Dimensions of Girder Bridges."

5. A George Stephenson Medal and a Telford Premium to Benjamin Baker,* M.Inst.C.E., for his paper on "The Actual Lateral Pressure of Earthwork."

6. A Telford Premium to Richard Henry Brunton,† M.Inst C.E., for his paper on the "Production of Paraffin and Paraffin Oils."

7. "A Telford Premium to Charles Colson† Asso.M.Inst.C.E., for his paper on "Portsmouth Dockyard Extension Works."

8. A Telford Premium to Christian Hendrick Meyer, Assoc.M.Inst.C.E., for his paper on the "Temporary Works and Plant at the Portsmouth Dockyard Extension."

9. A Telford Premium to Benjamin Walker, M.Inst.C.E., for his paper on "Machinery for Steel Making by the Bessemer and the Siemens' Processes."

10. The Manly Premium to Joseph Prime Maxwell, Assoc.M.Inst.C E., for his paper on "New Zealand Government Railways."

FOR PAPERS PRINTED IN THE PROCEEDINGS WITHOUT BEING DISCUSSED.

1. A Telford Medal and a Telford Premium to Professor Dr. J. Weyrauch, for his paper on "The Calculation of Dimensions as Depending on the Ultimate Working Strength of Materials."

2. A Telford Premium to James Richard Bell, M.Inst C.E., for his paper on "The Empress Bridge over the Sutlej."

3. A Telford Premium to John Lewis Felix Target,† M.Inst.C.E., for his paper, Experiments on Modules for Irrigation Purposes."

4. A Telford Premium to William Thomas Henney Carrington, Assoc M.Inst.C.E., for his paper on "Three Systems of Wire Rope Transport."

FOR PAPERS READ AT THE SUPPLEMENTAL MEETINGS OF STUDENTS.

1. A Miller Prize to James Bernard Hunter, Stud.Inst.C.E., for his paper on "Wood-Working Machinery as Applied to the Manufacture of Railway Carriages and Wagons."

2. A Miller Prize to Mathew Buchan Jamieson, Stud.Inst C.E., for his paper on "The Internal Corrosion of Cast-Iron Pipes."

3. A Miller Prize to Thomas Stewart, Stud. Inst.C.E., for his paper on "The Prevention of Waste of Water."

4. A Miller Prize to William Henry Edinger, Stud.Inst.C.E., for his paper on "Brick and Concrete and Concrete Gas-Holder Tanks."

5. A Miller Prize to Daniel Macalister, Stud. Inst.C.E., for his paper on "Caissons for Dock Entrances."

6. A Miller Prize to Lindsay Burnet,† Stud. Inst.C.E., for his "Description of a Cargo-Carrying Coasting Steam Ship, with Detailed Investigation as to its Efficiency."

7. A Miller Prize to Edward Walter Nealer Wood, Stud.Inst.C.E., for his paper on "The Improvement of the Old Harbor at Holyhead."

8. A Miller Prize to Arthur Stuart Vowell, Stud.Inst.C.E., for his paper on "Steel; its

Chemical Constitution and Behavior under Tensile Strain."

9. A Miller Prize to William Marriott, Stud. Inst. C.E., for his paper on "Boilers."

ENGINEERING NOTES.

Asphalt Carriageway Pavement.—At a recent meeting of the Streets Committee of the Commissioners of Sewers for the City of London, the following tenders were received for paving the roadway of Queen Victoria Street, from Mansion House to Cannon Street, area about 5,500 square yards:

Name of Contractors.	First cost per sq. yd.	Maintenance for 2 years free of cost to commissioners, and for 15 years (after 2 years expired) measured over the entire surface, at per sq. yd. per annum.	Total cost of pavement to commissioners at expiration of 17 years at per sq. yd.
French Asphalte Co., 27 Cornhill, E. C.	13s. 6d.	1s.	28s. 6d.
Limmer Co., 85 Gracechurch St E. C.	13s. 6d.	8d.	23s. 6d.
Val de Travers Co., Old Broad Street, E. C.	13s. 10d.	6d.	21s. 4d.

The Committee recommended the acceptance of the lowest tender: and it should be further mentioned that at the expiration of seventeen years the pavement is to be left in as good a state and condition as when first laid down, and with a smooth and even surface.

The Pittsburgh Suspension Bridge.—The suspension bridge connecting Pittsburgh and Allegheny, which was partially destroyed by fire recently, was a structure of some importance in the history of bridges. The suspension bridge, which replaced an old covered wooden structure, was finished in 1860, and was considered the finest in the world. The builder, Roebling, had not then acquired the European celebrity which came from the erection of the Cincinnati and Covington bridge. Mr. Roebling had a *carte blanche* to do as he saw fit, though he submitted all his projects to the company as he went along, and they were all endorsed. So perfect was the work considered that when the Prince of Wales and suite were here they were astonished to find such a work of art in what was then a rather small provincial town. The Duke of Newcastle, who was a very practical man, scrutinized the bridge closely, and informed the Prince that it was the best bridge he had ever seen. Before the war a dollar went a long way; what cost $300,000 then would cost $500,000 now. Roebling, the builder, when asked what was the strength of the bridge, said he had ascertained the power of the greatest hurricane that ever passed over Pittsburgh prior to 1858, and multiplied this by nine, which represented the strength of the bridge. President Harper says such power gave the company sufficient confidence in the power of the structure to resist pressure that no insurance against flood damage was considered necessary, especially as the bridge had been put 5 feet above the flood mark of 1832. It was considered almost impossible to set the bridge on fire, so since 1859 it has carried no insurance of any kind, and the company not only must stand the loss of several weeks' wagon travel, but must repair the damage themselves out of their accumulations.

The Channel Tunnel.—At a meeting of the proprietors of the South-Eastern Railway, held on the 16th inst., Sir Edward Watkin, M. P., the chairman, described the experimental works which had been undertaken, with the view to show whether the making of a tunnel under the Channel between England and France was feasible and practicable. The whole question, he said, divided itself into two parts. One was whether they could pass under the Channel through a stratum which was impervious to water. The second point was whether, by the aid of machinery, they could shorten very considerably the probable time of construction. What they had done was this: They had sunk two shafts on this side of the Channel; one at the Abbott's Cliff Tunnel, and the other on this side of the Shakespeare Cliff Tunnel. From the first of these shafts they had driven a gallery of from 800 to 900 yards, of a diameter of seven feet, which had all been excavated by machinery. Last week, with that machinery, which was not perfect, they excavated 67 yards of lineal distance on the extension of that gallery. If that were the maximum speed each week, it meant about two miles of progress a year. Of course, as they worked from two ends, and as the distance was only twenty miles, practically speaking, it meant five years to complete a gallery seven feet in diameter, as an experiment, under the whole length of the Channel. As to the second shaft, at the Shakespeare Cliff, they had sunk that down to a depth of 155 feet. They had also bored from the bottom of the shaft to a further depth of 106 feet. They had found no trace whatever of water in the old grey chalk. There was a small quantity of water near the surface, but this was always expected. He therefore thought that solved the great questions of the speed at which they could go, and of the impermeability of the strata to leakages of water. On the other side of the Channel the French company had sunk two very important shafts, and they had found exactly the same results as had been ascertained on this side. As to the machinery, they were on the eve of concluding another arrangement with Captain English, Colonel Beaumont, and M. Pigou, the proprietors of the machine with which they had been working. Under this new arrangement, they would pay merely for the use of the machine, and by means of it they would carry those experiments considerably further. It had been arranged between the French and English committees that they should drive

through a heading of a further length of one mile on each side When these two miles were finished—and they certainly ought to be in six months—one-tenth of the question was dealt with. If that were successful he should, he thought, propose a further treaty with the French gentlemen under which the remaining nine miles on each side would be done, and they would meet in the middle of the Channel. If that were successful, the whole question was practically settled. Until the matter was proved, however, neither the French nor the British investor would be asked to embark capital in the undertaking. The South-Eastern shareholders were, as it were, the founders of the feast. They had taken all the risk, and they had authorized an expenditure of not more than £20,000 upon the affair. Now a great deal of that which they wanted to prove had been proved. He meant to ask them to consider how best to make what had been proved more positive, and then to consider whether they should not get up a small limited liability company, or other company, to take the matter in hand, without further interfering with the finances of the South-Eastern Company. This was a question deserving serious consideration at their hands. They must, however, never forget that it was absolutely essential that this tunnel matter should remain under South-Eastern control.

ORDNANCE AND NAVAL.

Two New Clyde Steamers.—Within a short time there have been hand over to their owners two splendid new Clyde-built steamers of totally different types, one of them having been both built and engined by Messrs. John Elder & Co., Glasgow, and the other built by Messrs John Reid & Co., Port-Glasgow, and supplied with engines by Messrs. Rankin and Blackmore, Greenock. As they are both unusually fine examples of their respective types, it will not be out of place to give a short descriptive notice of them.

The vessel first referred to is a magnificent iron screw steamship named the Elbe, of nearly 5000 tons gross register, and is owned by the North German Lloyd Company, of Bremen. She is of the following dimensions: Length, 440 feet; breadth, 45 feet; depth, 36 feet 6 inches, and she is classed in highest grade of the Bureau Veritas, with several extras over their requirements, such as lower and orlop decks, and additional water-tight bulkheads All the decks and deck work are constructed either of teak or iron. In order to protect the vessel from the heavy Atlantic seas, strongly constructed iron turtle backs are placed over both ends of the ship. In addition to the accommodation for the officers and crew, 170 in number, the vessel is designed to carry 190 first-class, 120 second-class, and 1000 steerage passengers. The chief saloon, as is generally the case now-a-days in first-class vessels, is placed forward of the engines and boilers. It is a very handsome, beautifully lighted, and comfortable apartment, about 40 feet square, and was designed by Mr. Poppa, architect, Bremen, the style adopted being the German Renaissance. The Elbe is rigged with four pole masts of iron, with yards on the fore and main masts; and she is provided with steam windlass, steam and hand-steering gear, steam winches, steam hold pumps. steam "navy" pumps, fresh-water condenser, &c.; indeed, there are combined in her all the modern appliances for securing the safety of the vessel at sea, and facilitating the working of the cargo. The engines of the Elbe are of the three-cylinder type—one high-pressure cylinder having a diameter of 60 inches, and two low pressure cylinders each of 85 inches diameter, and having a stroke of 5 feet. The boilers, four in number, are double-ended, each 15 feet in diameter by 17 feet 6 inches long, constructed of iron for a working pressure of 80 pounds per square inch. There are 24 furnaces, made of mild steel, on Fox's patent corrugated system. Among the improvements in the machinery of the Elbe. mention may be made of the crankshaft, which consists entirely of Krupp's crucible cast steel, and is built up of separate pieces on a system introduced by the builders. The propeller shaft is hollow and made of Whitworth compressed steel. In accordance with Messrs. Elder & Co.'s recent practice in fitting out high-speed steamships, the propeller blades of the Elbe are made of manganese bronze, a material which is rapidly superseding iron and steel for the purpose in question. When running the measured mile in terms of the contract on the 18th of June, she attained a mean speed of 16.57 knots per hour, being .57 knots over that stipulated. One of the runs was accomplished at the rate of 17.145 knots. Altogether the engines worked very smoothly, there being no heating of bearings or priming of boilers. The indicated horse power attained was 6115, being about 700 above the contract figure, with 66½ revolutions per minute, working with a steam pressure of 76 pounds and 28-inch vacuum. On the previous day, when the builders' trial took place, the consumption of coal was 1.82 pound per indicated horse power per hour.

The other vessel, a very handsome steamer named the Laja, was, as we have said, built by Messrs. John Reid & Co., Port-Glasgow, and engined by Messrs. Rankin and Blackmore, Greenock, her owners being the Compania Sud Americana de Vapores en el Pacifico. She left the Clyde on the 18th for Liverpool *en route* for Valparaiso, to take up her station between that port and Panama. In many respects this vessel possesses features which differ entirely from those of the ordinary cargo and passenger steamer, inasmuch as the requirements of the trade in which she is to be engaged necessitated a special design as to internal construction. Her dimensions are as follows: Length, over all, 350 feet; breadth, 40 feet 6 inches; depth of hold to "shade deck," 39 feet; and her carrying capacity is about 3000 tons. The Laja has a double bottom, which is divided into four compartments for water ballast; and she has four decks, consisting of lower, main, awning, and "shade" decks. In the lower hold and 'tween decks there is space

for stowing 2000 tons of cargo, the loading and discharging of which are carried on from six side hatches on the main deck—three on each side—at all of which are placed steam winches. This latter deck has been specially fitted up for steerage passengers and cattle, provision having been made for 100 emigrants in the fore part, and between 500 and 600 cattle in the after part. On the awning deck the grand saloon, ladies' boudoir, state rooms, lavatories, and officers' quarters have been placed and fitted up in a style which reflects great credit on the skill and taste of the designers and builders, and bespeaks the liberality of the owners. The state cabin, which is placed amidships, is a very fine and airy compartment, measuring 45 feet by 30 feet, and liberally lighted from the roof and sides. We need not detail the decorations and fittings, but will content ourselves by saying that they are of great excellence and appropriateness; nor need we dwell upon the other accommodation which is provided for at least 124 first-class passengers. The "shade" deck of the Laja is a magnificent promenade, extending the entire length and breadth of the steamer. On the after part of this deck a kind of bazaar is usually held while the steamer is on her proper station. Natives are allocated so many feet of space upon which to expose their wares, which embrace every requisite and luxury. At each port of call the residents come on board, and there buy, sell, or barter—the steamer's deck being, in fact, the emporium whence the necessaries of life are distributed through various districts. Distilled water is also sold at places where fresh water is scarce. This floating and traveling bazaar is held on the after part of the deck, and in no way do the traders interfere with the passengers, who exclusively enjoy the fore part of the steamer. This deck is fitted up with the electric light on the Brush system, and the same light is made available for use in the loading and discharging of cargo by night. The captain's state room, chart room, &c., have been built on the fore part of this deck; but with the exception of a long row of seats which are placed down part of the center, the deck is nearly free from other incumbrance. The Laja has been fitted up with a great variety of modern appliances, including Paul's patent windlass, and Harrison's steam steering gear; and she is provided with nine life boats. She is rigged as a three-masted schooner, and has the old-fashioned clipper bow. Her engines are of the ordinary compound type, of 280 horse power nominal, and working up to something like 2500 indicated. The cylinders are 45 in. and 80 in. in diameter, with 54-inch stroke. She has four boilers, and has a four-bladed propeller which is made of steel. When on trial she made a speed of 14½ knots, which was deemed highly satisfactory, being much over the contract speed. Her machinery worked with the greatest smoothness during the trial.

RAILWAY NOTES.

Russian Railways.—Russian railways do not, from a commercial point of view, appear to be in a very satisfactory condition. The total returns of all the Russian railways are, according to the official reports recently published, 14 per cent. less for 1880 than they were for the year 1879. This reduced income is very unevenly distributed, for while on some lines it amounted to only 3 per cent. in 1880 against 1879, some of the southern lines showed a decrease of 25 per cent., and in one exceptional case even as much as 30 per cent. The three railways, the Nicolai, the Warsaw, and the Moscow Nishni Novgorod line, belonging to the great Russian Railway Company, had in 1880 a total income of £5,800,000, that is, £1,030,000, or nearly 18 per cent. less than in 1879. The reason assigned for this large falling off in railway returns is that it is due partly to a considerable reduction in the export trade, especially of corn, and partly to the inevitable consequences of a war, such as the Turko-Russian war; while if we accept the views of Mr. Karl Huber, late traffic manager of the Kharkov-Nicolaiev Railway, expressed in a lecture delivered some time ago at St. Petersburg, this unsatisfactory result is also largely occasioned by considerable extra expenditures, enforced upon the railway companies by some of the clauses of the Ministry for Communication, expenditures which, as the lecturer asserted, were in many cases quite unnecessary and in many others far too high. Such expenditures would, he contends, amount in all to not less than £1,600,000 for the Russian railways generally.

In spite of this unsatisfactory condition there are some very considerable extensions partly in course of construction, partly proposed, most of these being in the southeastern districts of European Russia, for the purpose of connecting the rich mineral districts of the Ural Mountains as well as the large corn-growing districts with the centers of industry and the places of export. Woronetz is to be connected with Kharkov, which will bring it in direct communication with Nicolaiev and Odessa. A deputation has again waited upon the Government petitioning for the building of the line from Nijni Novgorod, by Kazan, Menselinsk, Ekaterinburg to Tyumen, a distance of some 800 miles intersecting the Ural Mountain range at Ekaterinburg, and so far forming the first link in the chain of proposed overland connection to China. Another line from Samora, a station on the Syzrau Orenburg line is to lead over Bogoroslay and Ufa to Ekaterinburg. This latter railway, which will have a length of about 450 miles, would, in conjunction with the former, open up a very large and productive district principally to the Black Sea ports and Western Russia, which is now almost cut off from commerce on account of the very slow and expensive means of communication, all traffic being carried on by vehicles at about five times the rate of the highest railway tariff in Russia. Some 70 miles of the trans-Caspian railway are already finished, and other new lines are under consideration.

The Government intend to commence two new lines, the Krivoi-Roy railway and the Baskentshak line this year, they are together about 400 miles long, and are to be built on-

tirely at Government expense. The cost of these lines, which are to be carried out under the superintennence of Mr. Titow, late chief engineer of the Donez Railway, is calculated at £16,130 per mile; one of the main objects in building them at the present moment is to give employment to a large and almost destitute country population. Great difficulties are anticipated with the unskilled laborers, and there can be no doubt that agricultural laborers and carters, of which this population principally consists, are but indifferent raw material for railway work. One of the largest iron structures on the Krivoi-Roy line will be a bridge over the Dnieper near Ekaterinoslav.

IRON AND STEEL NOTES

Increasing the Use of Iron.—The Belgian Commission of Inquiry into Means for Increasing the Use of Iron, which was appointed in 1877, has lately issued its report. For the better consideration of the subject it has been divided into seven classes, namely, engineering construction, buildings, mining, railway stores and fixed plant, railway rolling stock, naval construction, military material and buildings. Almost the only suggestion which is made under the first heading, is that of substituting iron columns for stone piers in bridge building; whilst, in place of wood, iron screw piles are recommended for pile foundations, and iron for bridge roadways, as being both stronger and cheaper than wood. Reference is made to the employment of iron in marine piers, wharves, &c. The report urges its use in buildings wherever possible, especially in all those liable to fire, in which latter case iron floors, staircases, girders, &c., should be obligatory. Doors, shutters, roofing laths, &c., might also be constructed of this material.

For the lining of pit shafts iron is considered by the Commission to possess advantages, as in this manner the dimensions of the shaft would be reduced. In some cases it might replace wood in the permanent galleries; and there are many other purposes for which iron might be employed in mining work, to the exclusion of wood, and the obviation of its many disadvantages.

On the question of iron *versus* wooden sleepers, the report refers to the increasing preference given to the former, especially in Germany; but the Commission appears not to have had sufficient information before it to arrive at a decision. The Minister of Public Works has been requested to furnish a report on the subject.

On the question of naval construction, the opinion expressed is, that for vessels under 500 or 600 tons, wood is the cheaper material; whilst, as larger vessels are at the present time almost exclusively constructed of iron, no extension of its employment in this direction is suggested. For military purposes iron might be much more largely used than at present.

Practically, it would appear that the Commission offers scarcely any original suggestions for the employment of iron. Many of the points mentioned in the report have already been, to a great extent, successfully adopted; whilst on the most important point touched upon—that of iron *versus* wooden sleepers—the Commission discreetly refrains from expressing an opinion. Taken as a whole, it must be admitted (from the report) that its work is hardly likely to produce any practical result; but it may possibly lead to a more thorough consideration of the question, and thus attain some measure of usefulness.

Steel Plates in Russia.—According to the regulations now in force at the Russian Government yards the steel plates there used for shipbuilding or boiler making purposes are to be rolled from ingots containing from 0.18 to 0.22 per cent. of carbon, and in the case of the plates for boiler making the test samples have to stand a tensile strain of not less than 26 or more than 30 tons per square inch, and must elongate 20 per cent. in a length of 8 in. before fracture. Shipbuilding plates must have a breaking strain of between 26 and 31 tons per square inch, and must elongate not less than 17 per cent. in a length of 8 in. The hot and cold bending tests are the same as those of the English Admiralty for iron, but in the case of the cold bending tests the samples are to be placed for from 20 to 30 minutes in a cooling mixture giving a temperature of about zero Fahrenheit, and after this they must bend to the same angle as is required for iron at the ordinary temperature.

The Hardening of Steel.—The tempering of steel is a question which is attracting considerable attention at the present time, especially the relation between the metal and the gases which come into contact with it during the process of manufacture. An interesting communication on the subject was recently made to the Physical Society by Professor Chandler Roberts of the Royal School of Mines, and his principal result, though of a negative kind, is valuable as narrowing the question at issue. Professor Roberts began by tracing the history of our knowledge concerning the carburization of iron, from the work of Clonet at the end of last century to that of Margueritte in 1856. Margueritte showed that, although the conversion of iron into steel could be effected by contact with carbon even in the diamond form, it is nevertheless true that carbonic oxide ordinarily plays a considerable part in the process. Graham's paper "On the Occlusion of Gases," read in 1867, gave singular point to this conclusion by showing that carbonic oxide can penetrate to the center of a mass of iron. This gas is in fact introduced into the iron at a comparatively low temperature, while a high temperature is necessary to enable the metal to appropriate the carbon in order to become steel. The effect of occluded gases in iron and steel is now being carefully studied by metallurgists in general, and a committee of the Institution of Mechanical Engineers recently raised the question in one of their reports as to whether the hardening and tempering of iron and steel might not be pro-

duced by the expulsion of occluded gases during the heating process, and their subsequent exclusion by the sudden cooling and contraction. Professor Roberts has undertaken to answer this question, and by heating rods and spiral wires of steel *in vacuo*, by means of the electric current, and suddenly quenching them in cold mercury, he demonstrates that steel will harden when there are no gases to absorb. The metal was of course robbed of its occluded gases by means of an air pump connected to the vacuum chamber, and the parts which were quenched in the mercury were found to be glass hard, while those which did not reach the cold fluid were found to be quite soft. Professor Roberts therefore concluded that gases do not play any part in the process of hardening and tempering. Historically interesting are the facts mentioned by Professor Roberts, that as early as 1781 Bergman clearly stated that fixed air could give up its carbon to iron, and that Reaumur, in 1722, actually employed the Toricellian vacuum in experiments on the tempering of steel, the metal being placed red hot in a highly rarefied atmosphere, thereby anticipating the methods of to-day by more than 150 years. An interesting discussion followed the reading of the paper. Professor Hughes, who has made numerous experiments on the subject, expressed his opinion that the temper of steel was due to the chemical union of the iron with the carbon. At low temperatures this union takes place only in a slight degree, and hence in soft steel we have the carbon keeping aloof from the iron; but as the temperature is raised the combination is furthered, until in the case of grey or glass hard steel we have really a kind of diamond alloyed with iron. Sudden cooling is necessary to fix the combination, for in slow cooling the carbon separates out again from the iron. This theory is a very promising one, and is supported by a variety of facts; Mr. Stroh, for example, having observed that when an electric spark passes between two iron contact pieces and fuses them, the fused part becomes diamond-hard and will scratch a file. Recent researches by Mr. T. W. Hogg have also led him to a similar conclusion, namely, the temper of steel is due to the presence of an unstable compound of iron and carbon. The theory might very well be tested by chemical analysis in order to see whether the proportion of carbon appropriated by the metal increased with the temperature, or if any change took place in the refractive index of the steel. It was generally agreed by all the speakers at the meeting that the color of the surface of tempered steel depends on the temperature, and is due to the thickness of the film or skin of oxide; the blue film signifying a higher temperature than the yellow, as well as a thicker coating. In this connection Professor Hughes has demonstrated that the electric resistance of the film increases with the temperature. A novel illustration of metallic skins was furnished by Professor Guthrie, who exhibited a steel chain to which he had given a beautiful bluish-black protective coating by simply dipping it in melted nitrate of potash or common nitre. The process was discovered accidentally, and as the bloom improves the appearance of the metal, it will probably be applied to utensils of iron and fancy articles.

BOOK NOTICES.

Publications Received.

Monthly Weather Report for June. Washington: Government Office.

Exponent of the Principles of Moments. By W. S. Auchincloss, A.S.C. E. Reprint from Transactions of A.S.C. E.

Abstracts of Papers in Foreign Transactions and Periodicals. Vol. 64, Part 2. London: Published by Institution of Civil Engineers.

The Three Americas Railway.—By Several Authors. Saint Louis: W. S. Bryan.

The Editor of this collection of Essays is Mr. Hinton Rowan Helper. The writers of the principal Essays, five in number, are Messrs. Frank F. Hilder, Frederick A. Bulen, Wm. W. Archer, Frank De Yeaux Carpenter and Francis A. Deekens.

The proposed route for a railway which is intended to bind together North America, Central and South America, is, as set forth, by Mr. Helper: "I have a decided preference for a perfectly direct track all along down the twenty-eighth degree of longitude west from Washington (103° west from Greenwich) from the southern boundary of British America to the northern frontier of Mexico. The line thus indicated, from which I would only with reluctance deviate so much as a hair breadth, either to the right hand or the left, but would follow with such exactitude that the roadbed from the extreme north to the extreme south of our own Republic, would be as rectilineal as the straightest street in the most quadrangular city, intersects Dakota, Nebraska, Colorado, New Mexico and the western part of Texas. Thence in a perfectly straight line to the City of Mexico, then, as nearly midland as might be found advisable, through Guatemala and other Central American Republics to the Isthmus of Darien, and thence into South America, passing eastward of the Andes, felling the forests and furrowing up the surfaces of Columbia, Ecuador, Eastern Peru and Bolivia; thence in a nearly straight line to Rosario, Buenos Ayres and such other points in the Argentine Republic as the present needs of postal facilities and trade and travel may demand."

If anything connected with this scheme could be more striking than its political features, we are inclined to think the engineering ones will be when the road is fairly constructed on the proposed route.

Experimental Organic Chemistry. By Professor Chapman Jones. (London, Joseph Hughes.) New York: D. Van Nostrand.

This much neglected though most important branch of chemistry is, we are glad to see, at last receiving a little attention. It would be difficult to find language which would rightly

decribe the process now in vogue by which organic chemistry is supposed to be taught. After a course of lectures and a term spent over mineral chemistry, the student is set to prepare one or two organic re-agents that happen o be in demand, and his training is complete. The little book before us will, we think, do something towards putting an end to so absurd a method of teaching, and will at any rate supply a trusty and efficient basis for the student. Although not a pretentious book, it is, as the author says in his preface, practical and reasonable, the student being taught to observe and compare, instead of being asked to swallow isolated facts. The work is altogether free from fantastic theories, and we notice several pages that will be read with great interest by earnest students, who will be surprised to find that old friends can show such new faces. We especially notice the remarks on the definition of organic acids (pp. 60, 61), as being to the point and in advance of the notions promulgated in existing text books. To science teachers and candidates preparing for the Indian Civil Service this book will be found extremely useful.

TEXT-BOOK OF SYSTEMATIC MINERALOGY. By Hilary Bauerman. Longmans, Green & Co. 1881.

A systematic mineralogy has long been much wanted, which would occupy an intermediate position between the small elementary text-books which confine themselves to giving briefly and in a more or less disconnected form a general description of minerals, and the large works which partake more of the nature of a dictionary. The author of the work under consideration has endeavored to make the book connected and systematic throughout. Even if he had not succeeded, credit would be due to him for the attempt. It is extremely difficult in compiling a small text-book so to arrange that every part of the subject shall receive attention in exact proportion to its merits. In the endeavor to accomplish this, and at the same time to avoid giving meagre descriptions of important things, the author has been forced to consign descriptive mineralogy to another volume, not yet issued. It is true this would not have been necessary had a greater amount of knowledge on the part of the student been assumed. In this, however, we think the author has acted wisely. Instead of stating bare facts, he has prefaced them with a brief description of the principles on which the various phenomena depend. Thus, in treating of the optical properties of minerals, the various theories concerned, such as that of wave motion, are first elucidated. Whether these explanations of points relating to physics will be sufficient for a student without previous knowledge of the subject, is extremely doubtful; but even if they are not, they will materially assist him in obtaining the necessary information by marking out its nature and boundaries. The same thing may be said of the chapter relating to mineralogical chemistry. A student would be very unwise to attempt to obtain from this work alone the knowledge of chemistry requisite to any one studying mineralogy; but he may get useful hints as to the points to which his attention should be more especially directed.

About 200 pages of this book, containing in all about 390 pages, are devoted to physical crystallography. The methods here followed are mainly derived from Groth's treatise. The order adopted has, however, been reversed, and the geometrical properties of crystals are considered before their physical structure. The text is very free from printer's errors. We notice "dihexagonal" for tetragonal. The publishers are certainly to be complimented on their part of the work, and on having introduced to the public a book which will prove very useful to many. Those who would study mineralogy scientifically will find in this volume what is wanting in others which, in respect to price, are within the reach of those for whom this series of text-books was designed.

AID BOOK TO ENGINEERING ENTERPRISE ABROAD. By Ewing Matheson, M. Inst. C.E. London: E. and F. N. Spon, Charing-Cross.

Mr. Ewing Matheson, M. Inst. C. E., has brought out a second part of his valuable Aid Book, published in 1878. That book treated of the inception of public works and of the conditions on which success depends. The present part deals with the different modes of contracting, and enters into various particulars relating to the design or choice of machinery and material with a view to affording aid to foreign or colonial transactions. It would be impossible to give the reader anything but a very general idea of a book of nearly 500 closely printed pages, though a glance at a few chapters and the numerous marginal headings, interspersed here and there with engravings, will enable him to form a notion of the thorough manner in which Mr. Matheson has performed his task. The leading chapter on contract and purchase in the engineering trades is one of the most useful in the book. Speaking of prices and the value of preliminary agreements, the author shows how competitive prices ought to be based. The conditions must be the same in all cases, or the purchaser ought to be aware of the differences and have some standard by which to judge.

Purchase for Export, the Establishment of Factories, the Transmission of Power, are titles of other chapters of the book. In the last, steam, water, compressed air, connecting rods, shafting, &c., are considered, and the engineer or contractor will find the marginal headings numerous enough to assist him in making up his mind on almost any point as to the advantages to be derived from one or the other method; the cross-references and diagrams also are of considerable value. The remarks on hydraulic pressure, Armstrong's accumulator, and the proposal to adopt this and the Swiss plan of conducting high-pressure water through the streets for sale as power are interesting and full of useful data. Air compressors, rock drills and many other methods and motors are described, which the contractor or engineer will find convenient for reference. Coal, iron and steel, are also the subjects of another valuable

chapter. Thus we have the various classes and subdivisions of rolled iron described, such as L and T bars and joints, and the competing iron works in Germany, France and Belgium, are noticed. Much useful technical information will be found in this part on prices, tensile strength, and other tests into which it would be tedious and unnecessary to enter here, and the marginal headings give the text all the convenience and facilities of a dictionary. Fallacious brands are pointed out, and the dimensions of rolled bars of the usual sections for roofs and joists are given. It may be as well to remind the reader that L-bars are of more uniform quality and strength than T-bars, as the rolling is more favorable. Steel is also discussed in detail.

Passing a chapter on railway equipment, we come to a useful one on machine tools, forming a complete handbook on this extensive branch of engineering. Cranes—steam, hand and hydralic—are classified, illustrated and described, according to their use and value in construction, and the contractor will find much to interest him in this part; as also in the next on excavating machines, boring tools, rock drills, pile drivers, &c., about which occasional information may be needed. These various appliances are amply illustrated by small engravings in the margin, sufficient to give the contractor a fair idea of the construction. Thus the boring tools in use for proving foundations, worm augers, chisel drills, rock drills are illustrated, and every point about which a contractor or engineer may need to be informed is briefly explained.

The concluding chapters on Portland cement, iron roofs, buildings and lighthouses concern the architect and builder particularly, but we have no space to enter into these sections. The strength and qualities of cement, methods of manufacturing it, the modes of testing it by briquettes, tests by weight and fineness, and the usual specification qualities, mixture with sand, price and other items of permanent value for reference are given. Every variety of iron roof, modes of lighting and construction, the values of galvanized iron, zinc, copper, or other covering materials will be found illustrated by diagrams and their merits discussed, while fireproof buildings, and the conditions best to insure resistance to heat, are not overlooked. We may have something more to say on these chapters; a detailed review of the work, however, is not necessary to convince us of the thoroughness and value of Mr. Matheson's Aid Book for the contractor, engineer and architect, as it embodies every kind of information most likely to be required in contract work abroad, or, indeed, at home.—*Building News.*

MISCELLANEOUS.

COLD STORAGE.—The recent large increase in the quantities of fresh provisions imported from abroad, has necessitated the erection of suitable apparatus for dealing with such produce on its arrival in this country, as it is obvious much loss and inconvenience would arise by suddenly placing entire cargoes of (say) meat on the market at once, as would have to be done were the meat taken from the cooling chambers in the vessels in which it was imported directly into the ordinary temperatures usually obtaining in this country. To meet this daily increasing demand, companies are being formed for the special purpose of carrying on this business, and we lately had the pleasure of seeing such an arrangement, which has just been set to work under the general direction of Mr. Kilbourn, of 5 East India Avenue. The site of the cold storage chambers is most conveniently chosen, being the basement formed by the Southeastern Railway between Upper Thames street and the river, flanked by streets on two sides and having a wharf at the back. Arrangements are also under contemplation for enabling railway wagons to be lowered from the Southeastern line directly into the works. The system employed is by withdrawing the air from the chambers by means of a Beales exhauster capable of dealing with 15,000 cubic feet per hour, driven by a ten-horse engine, and supplied with steam by one of Fowler's locomotive boilers. Provision is made by which any of the eleven chambers can be placed in communication with the exhauster. The cooling of the air is accomplished by bringing it into contact with a sort of surface condenser placed close to the roof and formed of 6 in. cast-iron pipes, previously refrigerated brine being caused to circulate through these coils, underneath which wooden trays are placed to catch the moisture deposited on the pipes. The brine is cooled at present on Tellier's system, by bringing it into contact with pipes containing methylated ether, this ether being compressed in a cylinder driven by a separate engine. A numerous company were invited to witness the inauguration of the process, when the general principles of mechanical refrigeration were briefly explained by Mr. Kilbourn. The undertaking will doubtless be watched with much interest by all concerned in the food supply question. We have to thank Mr. Tallerman and the general manager as well as Mr. Kilbourn, for the information so freely placed at our disposal.—*London Paper.*

THE "LIGHTNING."—Last July a new system of propulsion, the invention of Mr. Thornycroft, which has been applied to that vessel, was inspected. It will be remembered that the Lightning, built in 1876, was the first of the now considerable fleet of torpedo vessels which has been supplied by Mr. John I. Thornycroft & Co., for the English navy, and that, fitted with an ordinary screw abaft the rudder, she attained upon her official trial, which took place in Stokes Bay, a speed of 18.54 knots per hour. The steering, however, on this occasion was not particularly good, the times of turning the circle being 3 min. 50 sec. to starboad and 3 min. 50 sec. to port; and so, with a view to improve the steering power, and, if possible, also the speed of the vessel, the Admiralty commissioned Messrs. Thornycroft & Co. to fit her up with the apparatus which was the subject of the trial last week. The apparatus consists of a propeller of small diameter encased in a cylinder, which carries

at its after-end fixed guide blades arranged in such a way as to throw the water from the propeller directly aft. Thus far it is similar to the propelling arrangement of Mr. Rigg and Mr. Parsons. It differs, however, considerably from all propelling arrangements of this type in having, the boss of the propeller prolonged in the form of a cone through the fixed guide blades to a considerable distance astern of the enveloping cylinder, the object being, by narrowing the area, to increase the velocity of the steam coming from the propeller while passing through the apparatus. In the case of the Lightning this cone is made in three parts —one consisting of the propeller boss, the second of the boss in the center of the guide blades, and the third attached to the rudder. On each side of the enveloping cylinder are fixed wing pieces, so arranged that when the rudder is put hard over, the wing piece on the opposite side closes the aperture leading from the screw on that side and turns the water entirely through the aperture on the opposite side. As the speed of the vessel had been found, on a preliminary trial, to be over 19 knots, and would be further verified by the Admiralty officials before the boat was taken over, it was not thought necessary to include a speed trial at Long Reach in the programme. After leaving Westminster Pier, where the party embarked, the vessel was made to circle in the river, and it was found that the circle to port was made in 1 min. 15 sec., and to starboard in 1 min. 5 sec.; a result which is a great improvement on her speed of turning on the occasion of her official trial. The stem of the boat was then secured to the pier and the stern propelled sideways, so as to make the vessel turn a complete semicircle against wind and tide round the stem as a center. The vessel was then run down to Woolwich and back, so as to afford some of the party an opportunity of having a short run at full speed, the passage through the Pool in going and returning affording many excellent opportunities for testing the extreme handiness of the vessel. Among the other improvements effected in the Lightning by the introduction of the new propelling arrangement may be mentioned the diminution in size of the propeller, the diameter being reduced from 5 feet 6 inches in the case of the original screw to 3 feet in the propeller now fitted—a very small diameter, indeed, seeing that in some of the recent preliminary trials, the power developed by the engines was 460 indicated horse power. Another important feature, and one which ought to be exceedingly valuable to torpedo operations, is the protection afforded to the screw by the tube in which it works and the grating in front from floating wreckage, &c., an improvement which will no doubt be fully appreciated by the Portsmouth officers. The Lightning will now be finished off and returned to Portsmouth, where she will resume her duties as tender to the Vernon Naval Torpedo School.

A NOVEL form of electric lamp for domestic purposes has been devised by Dr. Paget Higgs, an electrician of New York. The source of light, instead of an incandescent loop of platinum wire or carbonized fiber, is in this lamp a minute electric arc, the carbon points being very small, and separated by a distance hardly perceptible, but the tiny spark formed between them emits a light equal to that of forty candles. The most remarkable feature of the apparatus is, however, its adaptation to the use of stored electricity. Following the indications given by several recent investigators, the inventor has succeeded in forming "secondary batteries," filled with some substance which, by voltaic decomposition and subsequent chemical re combination, affords a practicable means of receiving and retaining an electric charge to be drawn upon afterwards in such quantity and at such times as may be desired. This gives a peculiar advantage in lighting ships or railway trains, but even where a continuous current can be had from a dynamo-electric machine, Dr. Higgs finds it advisable to interpose the secondary batteries for the purpose of equalizing and steadying the light. The principal objection to the electric lamps now used is their variability, and the light even of the incandescent wires flickers quite perceptibly with every vibration of the fly-wheel, so it may well be believed that such a means of accumulating energy would be useful.

Dr. Higgs' system has been so far perfected that a company is already formed, and terms are fixed for the introduction of the new light into private houses. The lamps as now arranged depend upon a weak voltaic battery for their supply of electricity. The current from this would be far too feeble to produce the voltaic arc, but the energy produced by its constant action is stored up in what is called the "secondary battery," and drawn thence as wanted; the total amount of energy produced by the small battery in twenty-four hours being quite sufficient, when drawn in a large stream from the secondary reservoir, to give a brilliant light for four or five hours. The carbons are treated chemically in some way, so that their consumption is slow, one pair lasting a week under ordinary use, and they can be replaced in a few seconds. Unlike all other forms of electric lamps hitherto employed which derive their energy from voltaic currents, the Higgs light is said to be very inexpensive, and the published offer of the company is to place the apparatus, with a number of lamps, in the house of any responsible person on a month's trial. At the end of the month, if the cost of chemicals for producing the light, added to the interest on the first cost of the apparatus, is more than would have been the expense of the same light from gas at the rate of seventy-five cents per thousand feet, the company will take back the whole without charge. The batteries are enclosed in a box which can be set on a shelf in any convenient place, and require no more attention than the house batteries now used for many purposes. An application of the same principle has been made for furnishing motive power; and it is said that a street car motor is about to be put into use which can be charged at the stations with electricity sufficient for a three hours' trip.

VAN NOSTRAND'S

ENGINEERING MAGAZINE.

NO. CLIV.—OCTOBER, 1881.—VOL. XXV.

WHIRLED ANEMOMETERS.*

From "Nature."

In the course of the year 1872, Mr. R. H. Scott, F. R. S., suggested to the Meteorological Committee the desirability of carrying out a series of experiments on anemometers of different patterns. This suggestion was approved by the committee, and in the course of the same year a grant was obtained by Mr. Scott from the Government grant administered by the Royal Society for the purpose of defraying the espenses of the investigation. The experiments were not, however, carried out by Mr. Scott himself, but were intrusted to Mr. Samuel Jeffery, then Superintendent of the Kew Observatory, and Mr. G. M. Whipple, then First Assistant, the present Superintendent.

The results have never hitherto been published, and I was not aware of their nature till on making a suggestion that an anemometer of the Kew Standard pattern should be whirled in the open air, with a view of trying that mode of determining its proper factor, Mr. Scott informed me of what had already been done, and wrote to Mr. Whipple, requesting him to place in my hands the results of the most complete of the experiments, namely, those carried on at the Crystal Palace, which I accordingly obtained from him. The progress of the inquiry may be gathered from the following extract from Mr. Scott's report in returning the unexpended balance of the grant:

"The comparisons of the instruments tested were first instituted in the garden of the Kew Observatory. This locality was found to afford an insufficient exposure.

"A piece of ground was then rented and enclosed within the Old Deer Park. The experiments here showed that there was a considerable difference in the indications of anemometers of different sizes, but it was not possible to obtain a sufficient range of velocities to furnish a satisfactory comparison of the instruments. Experiments were finally made with a rotating apparatus, a steam merry-go-round, at the Crystal Palace, which led to some results similar to those obtained by exposure in the Deer Park.

"The subject has however been taken up so much more thoroughly by Doctors Dohrandt and Thiesen (*vide* 'Repertorium für Meteorologie,' vols. iv. and v.), and by Dr. Robinson in Dublin, that it seems unlikely that the balance would ever be expended by me. I therefore return it with many thanks to the Government Grant Committee.

"The results obtained by me were hardly of sufficient value to be communicated to the Society."

On examining the records it seemed to me that they were well deserving of pub-

* "Discussion of the Results of some Experiments with Whirled Anemometers." Paper read at the Royal Society, by Prof. G. G. Stokes, Sec. R.S.

lication, more especially as no other experiments of the same kind have, so far as I know, been executed on an anemometer of the Kew standard pattern. In 1860 Mr. Glaisher made experiments with an anemometer whirled round in the open air at the end of a long horizontal pole,* but the anemometer was of the pattern employed at the Royal Observatory, with hemispheres of 3.75 inches diameter and arms of 6.725 inches, measured from the axis to the center of a cup, and so was considerably smaller than the Kew pattern. The experiments of Dr. Dohrandt and Dr. Robinson were made in a building, which has the advantage of sheltering the anemometer from wind, which is always more or less fitful, but the disadvantage of creating an eddying vorticose movement in the whole mass of air operated on; whereas in the ordinary employment of the anemometer the eddies it forms are carried away by the wind, and the same is the case to a very great extent when an anemometer is whirled in the open air in a gentle breeze. Thus, though Dr. Robinson employed among others an anemometer of the Kew pattern, his experiments and those of Mr. Jeffery are not duplicates of each other, even independently of the fact that the axis of the anemometer was vertical in Mr. Jeffery's and horizontal in Dr. Robinson's experiments; so that the greater completeness of the latter does not cause them to supersede the former.

In Mr. Jeffery's experiments the anemometers operated on were mounted a little beyond and above the outer edge of one of the steam merry-go-rounds in the grounds of the Crystal Palace, so as to be as far as practicable out of the way of any vortex which it might create. The distance of the axis of the anemometer from the axis of the "merry" being known, and the number of revolutions (n) of the latter during an experiment counted, the total space traversed by the anemometer was known. The number (N) of *apparent* revolutions of the anemometer, that is, the number of revolutions *relatively to the merry*, was recorded on a dial attached to the anemometer, which was read at the beginning and end of each experiment. As the machine would only go round one way the cups had to be taken off and replaced in a reverse position, in order to reverse the direction of revolution of the anemometer. The *true* number of revolutions of the anemometer was, of course, $N+n$, or $N-n$, according as the rotations of the anemometer and the machine were in the same or opposite directions.

The horizontal motion of the air over the whirling machine during any experiment was determined from observations of a dial anemometer with 3-inch cups on 8-inch arms, which was fixed on a wooden stand in the same horizontal plane as that in which the cups of the experimental instrument revolved, at a distance estimated at about 30 feet from the outside of the whirling frame. The motion of the centers of the cups was deduced from the readings of the dial of the fixed anemometer at the beginning and end of each experiment, the motion of the air being assumed as usual to be three times that of the cups.

The experiments were naturally made on fairly calm days, still the effect of the wind, though small, is not insensible. In default of further information, we must take its velocity as equal to the mean velocity during the experiment.

Let V be the velocity of the anemometer, W that of the wind, θ the angle between the direction of motion of the anemometer and that of the wind. Then the velocity of the anemometer relatively to the wind will be

$$\sqrt{V^2-2VW\cos\theta+W^2} \quad . \quad . \quad . \quad . \quad (a)$$

The mean effect of the wind in a revolution of the merry will be different according as we suppose the moment of inertia of the anemometer very small or very great.

If, as is practically the case, W be small as compared with V, the correction to be added to V on account of the wind may be shown to be $W\frac{2}{4}V$ on the first supposition, and $3W\frac{2}{4}V$ on the second.

Three anemometers were tried, namely, one of the old Kew standard pattern, one by Adie, and Kraft's portable anemometer. Their dimensions, &c., were as follows:

(*a*) *The Old Kew Standard.*—Diameter of arms between centers of cups 48 inches; diameter of cups 9 inches. Fixed

* "Greenwich Magnetical and Meteorological Observations," 1862, Introduction, p. li.

to machine at 22.3 feet from the axis of revolution.

(β) *Adie's Anemometer.*—Diameter of arms between centers of cups 13.4 inches; diameter of cups 2.5 inches. Fixed to machine at 20.7 feet from the axis of revolution.

(γ) *Kraft's Portable Anemometer.*—Diameter of arms between centers of cups 8.3 inches; diameter of cups 3.3 inches. Fixed to machine at 19.10 feet from the axis of revolution.

With each anemometer the experiments were made in three groups, with high, moderate, and low velocities respectively, averaging about 28 miles an hour for the high, 14 for the moderate, and 7 for the low. Each group again was divided into two subordinate groups, according as the cups were direct, in which case the directions of rotation of the merry and of the anemometer were opposite, or reversed, in which case the directions of the two rotations were the same.

The data furnished by each experiment were: the time occupied by the experiment, the number of revolutions of the merry, the number of *apparent* revolutions of the anemometer, given by the difference of readings of the dial at the beginning and end of the experiment, and the space S passed over by the wind, deduced from the difference of readings of the fixed anemometer at the beginning and end of the experiment.

The object of the experiment was of course to compare the mean velocity of the centers of the cups with the mean velocity of the air relatively to the anemometer. It would have saved some numerical calculation to have compared merely the spaces passed through during the experiment; but it seemed better to exhibit the velocities in miles per hour, so as to make the experiments more readily comparable with one another, and with those of other experimentalists. In the reductions I employed 4-figure logarithms, so that the last decimal in V in the tables cannot quite be trusted, but it is retained to match the correction for W, which it seemed desirable to exhibit to 0.01 mile.

On reducing the experiments with the low velocities I found the results extremely irregular. I was subsequently informed by Mr. Whipple that the machine could not be regulated at these low velocities, for which it was never intended, and that it sometimes went round fast, sometimes very slowly. He considered that the experiments in this group were of little, if any, value, and that they ought to be rejected. They were besides barely half as numerous as those of the moderate group. I have accordingly thought it best to omit them altogether.

In the complete paper tables are then given containing the reduced results of the individual experiments, and from them the mean results for the high and moderate velocities are collected in the following table, in which are also inserted the mean errors:

Anemometer.	Directions of rotation.	High velocities. Mom. inert. small. p. c.	m. e.	High velocities. Mom. inert. large. p. c.	m. e.	Moderate velocities. Mom. inert. small. p. c.	m. e.	Moderate velocities. Mom. inert. large. p. c.	m. e.
Kew.	Opposite..	122.6	2.4	121.9	2.3	115.1	4.9	113.2	5.2
	Alike	118.4	2.9	117.5	2.8	109.7	4.5	108.5	5.1
	Mean...	120.5	—	119.7	—	112.4	—	110.8	
Adie.	Opposite..	95.1	2.3	94.2	2.3	88.5	4.5	86.8	5.0
	Alike.....	98.0	6.5	97.3	6.5	82.6	7.3	81.0	7.3
	Mean...	96.5	—	95.7	—	85.5	—	83.9	
Kraft.	Opposite..	101.5	2.6	100.8	2.5	89.1	4.8	86.9	5.1
	Alike.....	100.8	1.2	99.4	1.3	87.8	5.0	86.0	6.0
	Mean..	101.1	—	100.1	—	88.4	—	86.4	

The mean errors exhibited in the above table show no great difference according, as we suppose, the moment of inertia of the anemometer small or large in correcting for the wind. From the mean errors we may calculate nearly enough, by the usual formulæ, the probable errors of the various mean percentages for rotations opposite and alike. The probable errors of these mean percentages come out as follows:

	For high velocities.		For moderate velocities.
Kew	1.0	..	2.7
Adie	1.5	..	2.0
Kraft	0.9	..	1.8

These probable errors are so small that it appears that for the high and even for the moderate velocities the experiments are extremely trustworthy, except in so far as they may be affected by *systematic* sources of error.

It may be noticed that the difference of the percentages, according as the directions of rotation of the anemometer and of the merry are opposite or alike, is greatest for the Kew, in which the ratio of r to R is greatest, r denoting the radius of the arm of the anemometer, and R the distance of its axis from the axis of revolution of the machine, and appears to be least (when allowance is made for the two anomalous experiments in the group "Adie H +") for the Kraft, for which r/R is least. In the Kraft indeed the differences are roughly equal to the probable errors of the means. In these whirling experiments r/R is always taken small, and we might expect the correction to be made on account of the finiteness of R to be expressible in a rapidly converging series according to powers of r/R, say

$$\mathrm{A}'\frac{r}{\mathrm{R}}+\mathrm{B}'\left(\frac{r}{\mathrm{R}}\right)^2+\mathrm{C}'\left(\frac{r}{\mathrm{R}}\right)^3+\ldots$$

We may in imagination pass from the case of rotations opposite to that of rotations alike, by supposing R taken larger and larger in successive experiments, altering the angular velocity of revolution so as to preserve the same linear velocity for the anemometer, and supposing the increase continued until R changes sign in passing through infinity, and is ultimately reduced in magnitude to what it was at first. The ideal case of $\mathrm{R}=\infty$ is what we aim at, in order to represent the motion of a fixed anemometer acted on by perfectly uniform wind by that of an anemometer uniformly impelled in a rectilinear direction in perfectly still air. We may judge of the magnitude of the leading term in the above correction, provided it be of an odd order, by that of the difference of the results for the two directions of rotation. Unless therefore we had reason to believe that A′ were o, or at least very small compared with B′, we should infer that the whole correction for the finiteness of R is very small, and that it is practically eliminated by taking the mean of the results for rotations opposite and rotations alike.

We may accept, therefore, the mean results as not only pretty well freed from casual irregularities which would disappear in the mean of an infinite number of experiments, but, also, most probably, from the imperfection of the representation of a rectilinear motion of the anemometer by motion in a circle of the magnitude actually employed in the experiments.

Before discussing further the conclusions to be drawn from the results obtained, it will be well to consider the possible influence of systematic sources of error.

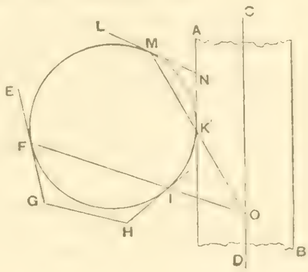
1. *Friction.*—No measure was taken of the amount of friction, nor were any special appliances used to reduce it; the anemometers were mounted in the merry just as they are used in actual registration. Friction arising from the weight is guarded against as far as may be in the ordinary mounting, and what remains of it would act alike in the ordinary use of the instrument and in the experiments, and as far as this goes, therefore, the experiments would faithfully represent the instrument as it is in actual use. But the bearings of an anemometer have also to sustain the lateral pressure of the wind, which in a high wind is very considerable; and the construction of the bearing has to be attended to in order that this may not produce too much friction. So far the whirled instrument is in the same condition as the fixed. But besides the friction arising from the pressure of the artificial wind, a pressure which acts in a direction tangential to the circular path of the whirled anemometer, there is the pressure arising from the centrifugal force. The highest velocity in the experiments was about thirty miles an hour, and at this rate the centrifugal force would be about three times the weight of the anemometer. This pressure would considerably exceed the former, at right angles to which it acts, and the two would compound into one equal to the square root of the sum of their squares. The resulting friction would exceed a good deal that arising from the

pressure of the wind in a fixed anemometer with the same velocity of wind, natural or artificial, and would sensibly reduce the velocity registered, and accordingly raise the coefficient which Dr. Robinson denotes by m, the ratio, namely, of the velocity of the wind to the velocity of the centers of the cups. It may be noticed that the percentages collected in the above table are very distinctly lower for the moderate velocities than for the high velocities. Such an effect would be produced by friction; but how far the result would be modified if the extra friction due to the centrifugal force were got rid of, and the whirled anemometer thus assimilated to a fixed anemometer, I have not the means of judging, nor again how far the percentages would be still further raised if friction were got rid of altogether.

Perhaps the best way of diminishing friction in the support of an anemometer is that devised and employed by Dr. Robinson, in which the anemometer is supported near the top on a set of spheres of gun-metal contained in a box with a horizontal bottom and vertical side which supports and confines them. For vertical support this seems to leave nothing to be desired, but when a strong lateral pressure has to be supported as well as the weight of the instrument, it seems to me that a slight modification of the mode of support of the balls might be adopted with advantage. When a ball presses on the bottom and vertical side of its box, and is at the same time pressed down by the horizontal disc attached to the shaft of the anemometer which rests on the balls, it revolves so that the instantaneous axis is the line joining the points of contact with the fixed box. But if the lateral force of the wind presses the shaft against the ball, the ball cannot simply roll as the anemometer turns round, but there is a slight amount of rubbing.

This, however, may be obviated by giving the surfaces where the ball is in contact other than vertical or horizontal direction.

Let AB be a portion of the cylindrical shaft of an anemometer: CD the axis of the shaft: EFGHI a section of the fixed box or cup containing the balls; LMN a section of a conical surface fixed to the shaft by which the anemometer rests on its balls; FIKM a section of one of the balls; F, I, the points of contact of the ball with the box; M the point of contact with the supporting cone; K the point of contact, or all but contact, of



the ball with the shaft. The ball is supposed to be of such size that when the anemometer simply rests on the balls by its own weight, being turned perhaps by a gentle wind, there are contacts at the points M, F, I, while at K the ball and shaft are separated by a space which may be deemed infinitesimal. Lateral pressure from a stronger wind will now bring the shaft into contact with the ball at the point K also, so that the box on the one hand and the shaft with its appendage on the other will bear on the ball at four points. The surface of the box, as well as that on the cone LN, being supposed to be one of revolution round CD, those four points will be situated in a plane through CD, which will pass of course through the center of the ball.

If the ball rolls without rubbing at any one of the four points F, I, K, M as the anemometer turns round, its instantaneous axis must be the line joining the points of contact F, I, with the fixed box. But as at M and K likewise there is nothing but rolling, the instantaneous motion of the ball may be thought of as one in which it moves as if it were rigidly connected with the shaft and its appendage, combined with a rotation over LNAB, supposed fixed. For the two latter motions the instantaneous axes are CD, MK respectively. Let MK produced cut CD in O. Then since the instantaneous motion is compounded of rotations round two axes passing through O, the instantaneous axis must pass through O. But this axis is FI. Therefore FI must pass through O. Hence the two lines FI, MK must intersect the axis of the

shaft in the same point, which is the condition to be satisfied in order that the ball may roll without rubbing, even though impelled laterally by a force sufficient to cause the side of the shaft to bear on it. The size of the balls and the inclinations of the surfaces admit of considerable latitude subject to the above condition. The arrangement might suitably be chosen something like that in the figure. It seems to me that a ring of balls constructed on the above principle would form a very effective upper support for an anemometer whirled with its axis vertical. Possibly the balls might get crowded together on the outer side by the effect of centrifugal force. This objection, should it be practically found to be an objection, would not of course apply to the proposed system of mounting in the case of a fixed anemometer. Below, the shaft would only require to be protected from lateral motion, which could be done either by friction wheels or by a ring of balls constructed in the usual manner, as there would be only three points of contact.

2. *Influence on the Anemometer of its own Wake.*—By this I do not mean the influence which one cup experiences from the wake of its predecessor, for this occurs in the whirling in almost exactly the same way as in the normal use of the instrument, but the motion of the air which remains at any point of the course of the anemometer, in consequence of the disturbance of the air by the anemometer, when it was in that neighborhood in the next preceding and the still earlier revotions of the whirling instrument.

It seems to me that in the open air, where the air impelled by the cups is free to move into the expanse of the atmosphere, instead of being confined by the walls of a building, this must be but small, more especially as the wake would tend to be carried away by what little wind there might be at the time. On making some inquiries from Mr. Whipple as to a possible vorticose movement created in the air through which the anemometer passed, he wrote as follows: "I feel confident that under the circumstances the tangential motion of the air at the level of the cups was so small as not to need consideration in the discussion of the results. As in one or two points of its revolution the anemometer passed close by some small trees in full leaf, we should have observed any eddies or artificial wind had it existed, but I am sure we did not."

3. *Influence of the Variation of the Wind; first, as regards Variations which are not Rapid.*—During the twenty or thirty minutes that an experiment lasted there would of course be numerous fluctuations in the velocity of the wind, the mean result of which is alone recorded. The period of the changes (by which expression it is not intended to assert that they were in any sense regularly periodic) might be a good deal greater than that of the merry, or might be comparatively short. In the high velocities, at any rate, in which one revolution took only three or four seconds, the supposition that the period of the changes was large compared with one revolution is probably a good deal nearer the truth than the supposition that it is small.

On the former supposition the correction for the wind during two or three revolutions of the merry would be given by the formulæ already employed, taking for W its value at the time. Consequently the total correction will be given by the formulæ already used if we substitute the mean of W^2 for the square of mean W. The former is necessarily greater than the latter, but how much we cannot tell without knowing the actual variations. We should probably make an outside estimate of the effect of the variations if we supposed the velocity of the wind twice the mean velocity during half the duration of the experiment, and nothing at all during the remainder. On this supposition the mean of W^2 would be twice the square of mean W, and the correction for the wind would be doubled. At the high velocities of revolution, the whole correction for the wind is so very small that the uncertainty arising from variation as above explained is of little importance, and even for the moderate velocities it is not serious.

4. *Influence of Rapid Variations of the Wind.*—Variations of which the period is a good deal less than that of the revolutions of the whirling instrument act in a very different manner. The smallness of the corrections for the wind hitherto employed depends on the circumstance

that with uniform wind, or even with variable wind, when the period of variation is a good deal greater than that of revolution of the merry, the terms depending on the first power of W, which letter is here used to denote the momentary velocity of the wind, disappear in the mean of a revolution. This is not the case when a particular velocity of wind belongs only to a particular part of the circle described by the anemometer in one revolution. In this case there will in general be an outstanding effect depending on the first power of W, which will be considerably larger than that depending on W^2. Thus suppose the velocity of whirling to be thirty miles an hour, and the average velocity of the wind three miles an hour, the correction for the wind supposed uniform, or if variable, then with not very rapid variations, will be comparable with 1 per cent. of the whole; whereas, with rapid variations, the effect in any one revolution may be comparable with 10 per cent. There is, however, this important difference between the two: that whereas the correction depending on the square leaves a positive residue, however many experiments be made, the correction depending on the first power tends ultimately to disappear, unless there be some cause tending to make the average velocity of the wind different for one azimuth of the whirling instrument from what it is for another. This leads to the consideration of the following conceivable source of error.

5. *Influence of Partial Shelter of the Whirling Instrument.*—On visiting the merry-go-round at the Crystal Palace, I found it mostly surrounded by trees coming pretty near it, but in one direction it was approached by a broad open walk. The consequence is that the anemometer may have been unequally sheltered in different parts of its circular course, and the circumstances of partial shelter may have varied according to the direction of the wind. This would be liable to leave an uncompensated effect depending on the first power of W. I do not think it probable that any large error was thus introduced, but it seemed necessary to point out that an error of the kind may have existed.

The effect in question would be eliminated in the long run if the whirling instrument were capable of reversion, and the experiments were made alternately with the revolution in one direction, and the reverse. For then, at any particular point of the course at which the anemometer was more exposed to wind than on the average, the wind would tend to increase the velocity of rotation of the anemometer for one direction of revolution of the whirling instrument just as much, ultimately, as to diminish it for the other. Mere reversion of the cups has no tendency to eliminate the error arising from unequal exposure in different parts of the course. And even when the whirling instrument is capable of reversion it is only very slowly that the error, arising from partial shelter, is eliminated compared with that of irregularities in the wind; of those irregularities, that is to say, which depend on the first power of W. For these irregularities go through their changes a very great number of times in the course of an experiment lasting perhaps half an hour, whereas the effect of partial shelter acts the same way all through one experiment. It is very desirable therefore that in any whirling experiments carried on in the open air, the condition of the whirling instrument as to exposure or shelter should be the same all round.

The trees, though taller than the merry when I visited the place last year, were but young, and must have been a good deal lower at the time that the experiments were made. Mr. Whipple does not think that any serious error is to be apprehended from exposure of the anemometer during one part of its course and shelter during another.

From a discussion of the foregoing experiments it seems to me that the following conclusions may be drawn:

1. That, at least for high winds, the method of obtaining the factor for an anemometer, which consists in whirling the instrument in the open air, is capable, with proper precautions, of yielding very good results.

2. That the factor varies materially with the pattern of the anemometer. Among those tried, the anemometers with the larger cups registered the most wind, or in other words required the lowest factors to give a correct result.

3. That with the large Kew pattern,

which is the one adopted by the Meteorological Office, the register gives about 120 per cent. of the truth, requiring a factor of about 2.5, instead of 3. Even 2.5 is probably a little too high, as friction would be introduced by the centrifugal force, beyond what occurs in the normal use of the instrument.

4. That the factor is probably higher for moderate than for high velocities; but whether this is solely due to friction the experiments do not allow us to decide.

Qualitatively considered, these results agree well with those of other experimentalists. As the factor depends so much on the pattern of the anemometer it is not easy to find other results with which to compare the actual numbers obtained, except in the case of the Kew standard. The results obtained by Dr. Robinson, by rotating an anemometer of this pattern without friction purposely applied are given at pp. 797 and 799 of the *Phil. Trans.* for 1878. The mean of a few taken with velocities of about 27 miles an hour in still air gave a factor 2.36, instead of 2.50 as got from Mr. Jeffery's experiments. As special anti friction appliances were used by Dr. Robinson, the friction in Mr. Jeffery's experiments was probably a little higher. If such were the case the factor ought to come out a little higher than in Dr. Robinson's experiments, which is just what it does. As the circumstances of the experiments were widely different with respect to the vorticose motion of the air produced by the action of the anemometer in it, we may, I think, conclude that no very serious error is to be apprehended on this account.

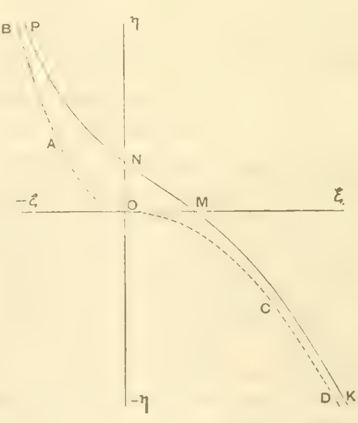
In a later paper (*Phil. Trans.* for 1880, p. 1055), Dr. Robinson has determined the factor for an anemometer (among others) of the Kew pattern by a totally different method, and has obtained values considerably larger than those given by the former method. Thus the limiting value of the factor m corresponding to very high velocities, is given at p. 1063 as 2.826, whereas the limiting value obtained by the former method was only 2.286. Dr. Robinson has expressed a preference for the later results. I confess I have always been disposed to place greater reliance on the results of the Dublin experiments, which were carried out by a far more direct method, in which I cannot see any flaw likely to account for so great a difference. It would be interesting to try the second method in a more favorable locality.

I take this opportunity of putting out some considerations respecting the general formula of the anemometer, which may perhaps not be devoid of interest.

The problem of the anemometer may be stated to be as follows: Let a uniform wind with velocity V act on a cup anemometer of given pattern, causing the cups to revolve with a velocity v, referred to the center of the cups, the motion of the cups being retarded by a force of friction F; it is required to determine v as a function of V and F, F having any value from O, corresponding to the ideal case of a frictionless anemometer, to some limit F_1, which is just sufficient to keep the cups from turning. I will refer to my appendix to the former of Dr. Robinson's papers (*Phil. Trans.* for 1878, p. 818), for the reasons for concluding that F is equal to V^2, multiplied by a function of V/v. Let

$$V/v=\xi, \qquad F/V^2=\eta,$$

then if we regard ξ and η as rectangular co-ordinates we have to determine the form of the curve, lying within the positive quadrant $\xi o \eta$, which is defined by those co-ordinates.



We may regard the problem as included in the more general problem of determining v as a function of V and F, where V is positive, but F may be of any

magnitude and sign, and therefore v also.* Negative values of F mean, of course, that the cups, instead of being retarded by friction, are acted on by an impelling force making them go faster than in a frictionless anemometer, and values greater than F_1 imply a force sufficient to send them round with the concave sides foremost.

Suppose now F to be so large, positive or negative, as to make v so great that V may be neglected in comparison with it, then we may think of the cups as whirled round in quiescent air in the positive or usual direction when F is negative, in the negative direction when F is greater than F_1. When F is sufficiently large the resistance may be taken to vary as v^2. For equal velocities v it is much greater when the concave side goes foremost than when the rotation is the other way. For air impinging perpendicularly on a hemispherical cup Dr. Robinson found that the resistance was as nearly as possible four times as great when the concave side was directed to the wind as when the convex side was turned in that direction (*Transactions* of the Royal Irish Academy, vol. xxii. p. 163). When the air is at rest and the cups are whirled round, some little difference may be made by the wake of each cup affecting the one that follows. Still we cannot be very far wrong by supposing the same proportion, 4 to 1, to hold good in this case. When F is large enough and negative, F may be taken to vary as v^2, say, to be equal to—Lv^2. Similarly, when F is large enough and positive, F may be taken equal to $L'v^2$, where in accordance with the experiment referred to, L' must be about equal to 4 L. Hence we must have nearly

$\eta = -L\xi^2$, when ξ is positive and very large;

$\eta = 4\,L\xi^2$, when ξ is negative and very large.

Hence, if we draw the semi-parabola O A B corresponding to the equation $\eta = 4L\xi^2$ in the quadrant $\eta O-\xi$, and the semi-parabola O C D with a latus lectum four times as great in the quadrant $\xi O-\eta$, our curve at a great distance from the origin must nearly follow the parabola O A B in the quadrant $\eta O-\xi$, and the parabola O C D in the quadrant $\xi O-\eta$, and between the two it will have some flowing form such as P N M K. There must be a point of inflection somewhere between P and K, not improbably within the positive quadrant $\xi O-\eta$. In the neighborhood of this point the curve N M would hardly differ from a straight line. Perhaps this may be the reason why Dr. Robinson's experiments in the paper published in the *Phil. Trans.* for 1878 were so nearly represented by a straight line.

* Of course v must be supposed not to be so large as to be comparable with the velocity of sound, since then the resistance to a body impelled through air, or having air impinging on it, no longer varies as the square of the volocity.

NOTE ON THE FRICTION OF TIMBER PILES IN CLAY.

By ARTHUR CAMERON HERTZIG, Assoc. M. Inst. C.E.

From Selected Papers of the Institution of Civil Engineers.

The frictional resistance to motion of piles in different soils is not easily ascertained or well known. The difficulty arises from the fact that when piles are once driven in the foundations of bridges, &c., no occasion, as a rule, occurs by which their adhesion can be afterwards determined. In isolated cases, where foundations have failed, an approximate connection has been formed between the superincumbent weight and the frictional resistance of the piles; these cases, though not numerous, afford some information on the subject. Direct experiments are also but few, so that the data from which to obtain a correct knowledge are not ample. As a small contribution the author submits the present short note of several observations.

The removal of a cofferdam of whole-timber piles at Hull gave the opportunity for taking the observations.

Previous to the extension of the Albert dock westward a circular cofferdam was driven at the west end of the dock, to keep out the water from the new works. This dam consisted of two rows of whole-

timber piles, 5 feet apart, the radius of the outer row being 205 feet. The intervening space was filled with puddled clay to above high-water mark. The dam was made in 1874, and the piles, after remaining in the ground five years, were drawn in January and February, 1880.

The clay was reached at a depth of 28 feet below the level of the quay. This was a compact bluish clay, and above it there were from 3 to 5 feet of peat, above which again were silt and sand. The west end of the Albert dock was finished with a pitched slope at an inclination of 3 to 1, and the dam was driven into this slope, the points of the piles entering the ground at about the level of the peat, or slightly above. Thus the piles may be considered as having been chiefly in the stiff blue clay. Before the piles were drawn the clay puddle between the two rows was removed to as low a point as possible, which was about 13 feet below the level of the quay, or rather under high-water mark of ordinary neap tides. The clay puddle that could not be removed would increase to a small extent the frictional resistance to drawing. The clay having been got out the piles were drawn, commencing at the north end of the dam.

A "cat head" was used to draw the piles. This consisted of a framework of whole timbers, to the cross head of which was fixed the tackle for lifting—a pair of blocks and six-part chain. The free end of the chain was led round the barrel of a winch, capable of being worked by single or double purchase. The whole of the apparatus stood upon a platform upon the heads of the piles, and was shifted southward as the piles northward were drawn. To the lower pulley block a heavy sling chain was attached, and this was slung round the pile to be drawn and secured with wedges.

The power exerted by one, two or more men working at the apparatus was previously ascertained by allowing them to lift certain known dead weights with the winch and tackle, under exactly the same conditions as those under which they were used in drawing the piles of the dam. The radius of the handle of the winch was 18 inches, and it was found that the extreme power which a man could put into the machine throughout the revolution was 27 lbs. effective. That is to say, the extreme weight that could be raised by one man, together with the friction of the apparatus, was represented by 27 lbs. at the handle. The same men employed in drawing the dam worked the winch to ascertain the weights lifted; these were as follows:

Number of men.	Single purchase.		Double purchase.	
	Tons.	cwt.	Tons.	cwt.
1	2	10	9	10
2	4	0	15	0
3	6	0	22	10
4	7	10	28	0
5	9	10	35	10
6	11	0	41	0

The winch was generally used in double purchase, and in commencing to draw a pile perhaps three men were first put at the handle. If they could not move the pile four were tried, and if these could not do it then five, and so on. Suppose, for instance, five men were able to draw the pile, while four could not; the ganger in charge would enter in his book, kept for the purpose, whether the pile which would not move with four men at the handle, moved easily or otherwise when five were tried. Three degrees were used to designate the difficulty in drawing, viz., "easy," "hard," and "very hard," and against each pile in the book was entered the corresponding degree of difficulty experienced in drawing it. Thus, knowing the extreme loads that four and five men could lift, it was possible to estimate approximately the actual pull required to draw the pile. It would have been easy with a dynamometer to have had the exact pull registered in every case; but such an instrument was not available, and the author had to be contented with the approximate estimate. The results, though not pretending to great accuracy, are perhaps as useful as if they did; for in any case where the knowledge of the friction in earth is required, it is sufficient to be able to estimate to within a few tons.

In addition to the observation on the pull required to draw the pile, the length and scantling of each pile were taken, and also the depth to which it had been driven in the ground. These were all the observations required.

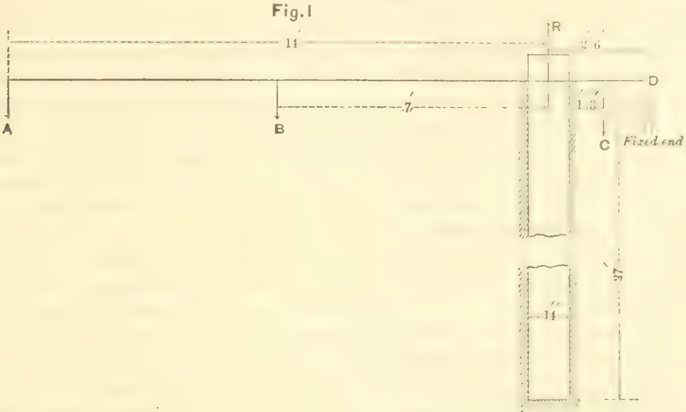
Four hundred and twenty piles were drawn, upon which three hundred observ-

ations were taken. The length varied between 20 feet and 49 feet, a few of the short piles being used in the south end of the dam, where it met the pitched slope of the side of the dock. The average length of all was 40 feet. The average scantling was 12½ inches square = 156 square inches, the sizes varying between 12 inches by 10 inches = 120 square inches, and 15 inches by 14 inches = 210 square inches. The depths to which the piles were driven in the ground ranged between 6 feet and 30 feet, the average being 18¼ feet. The average superficial area of pile below the ground line was 76 feet.

As the piles were not tongued and grooved, but simply driven close together, and as they were drawn consecutively, only two sides of each pile would have to be taken in estimating the area to which the friction in the soil was due. The average area below ground being 76 square feet, half of this, or 38 square feet, will be subject to friction. The gross resistance, as measured by the pull required to draw three hundred piles, was 33.87 tons per pile. From this must be deducted two items, the weight of the pile and the power required to overcome the suction. For the piles of average scantling, 12½ inches square, there will be required a maximum pull of 156 × 15 lbs. = 2,340 lbs. to overcome the resistance of suction, taking the worst condition, viz., that of a perfect vacuum. The weight of the pile containing 44 cubic feet may be taken at 1 ton. Thus, making allowance for these items, the net frictional resistance of the soil will be 31.82 tons per pile; and this, on an area of 38 superficial feet, gives 1,875 lbs. as the co-efficient of friction per square foot in contact with the soil. The piles were of ordinary rough Memel balk timber. With sawn timber there would probably be a slight reduction in the friction.

In other soils, and with a surface other than timber, the co-efficient would be different. During the progress of a 14-inch boring for water the author observed what force was required to press down the tube lining the hole. This lining was of iron tubing, 14 inches in diameter, and $\frac{1}{16}$ inch thick. The bottom of the tube had reached a depth of 24 feet, and the boring tool was working at a depth of 28 feet, having passed through 20 feet of made ground and 8 feet of silty clay. The hole having been cleared out, the tube was forced down as follows:

Fig. I



A = weight of two men = 3 cwt.

B = weight of 14 feet. length of four planks 12½ inches by 3 inches = 7 cwt.

C = weight of 2 feet 6 inches length of same planks = 1¼ cwt.

R = the resistance opposed by the tube.

The end D of the planks being anchored down, it follows from the above that R = 47 cwt. The depth being 27 feet, and the diameter 14 inches, the superficial area in contact with the earth = 100 square feet; so that the skin friction of the tube in this light earth amounted to 0.47 cwt. per square foot = 53 lbs.

Several examples of the friction of soils

on piles and piers are recorded in the Minutes of Proceedings.

In close connection with this subject is the relation between the energy imparted to a pile in driving and the weight it will afterwards carry, or the force required to draw it, if it be assumed that friction only is the resistance to motion in each case. The author has deduced a simple formula for ascertaining the extreme load that could be carried by a pile after a definite amount of driving.

If P = the extreme resistance of the pile in tons,

x = the energy of the last blow, in foot-tons = the product of the weight of the monkey into the height of fall,

y = the "set" of the pile at the last blow, in feet, then the formula is:

$$y=\frac{x}{P}-\frac{P}{500}.$$

The piles in the dam were driven with a 1-ton monkey falling 5 to 6 feet, and the set of the pile under the last blow varied between $\frac{1}{2}$ and $\frac{3}{4}$ inch.

Applying these quantities to the preceding formula, the extreme resistance is from 35 to 45 tons, while the average resistance to the drawing of the piles was actually something under 34 tons—a result which shows that the formula is tolerably correct for the extreme supporting power of a pile in its worst condition, that of resistance by lateral friction only.

THE PROTECTIVE WORKS FOR PREVENTING THE THREATENED OUTBREAK OF THE SOUTH RANGITATA RIVER, N. Z.

By JOHN HENRY LOWE, M. Inst. C. E.

From Selected Papers of the Institution of Civil Engineers.

Since the construction of railways in the Middle Island of New Zealand, the sudden and violent floods to which the country is liable have occasioned much trouble and expense. The rivers which traverse the Canterbury plains are amongst the most formidable when in flood.

These plains form the central portion of the eastern slope of the Middle Island. They extend for a length of about 100 miles, by a breadth of 40 miles, from the sea to the foot of the mountain ranges, and are composed almost entirely of shingle of great depth, overlaid with a light sandy soil, principally covered with tussock grass. The plains, although presenting to the eye the appearance of an unbroken level, have a fall towards the sea varying from 18 feet to 40 feet to the mile.

Three principal rivers—the Waimakariri, the Rakaia and the Rangitata—traverse these plains, and are mainly fed by the melting snows of the Southern Alps, augmented by the copious rains that fall over their extensive basins. Numerous minor streams and watercourses also intersect the plains, rising among the lower hills at the foot of the main ranges. The Waimakariri, the most northerly of these rivers, flows about 14 miles northward of Christchurch. It is the only one that has yet extended its bed beyond the limits of the gravels. The others are still discharging gravels into the sea. No doubt the plains have been formed by the accumulated deposits of shingle brought down, through a long course of time, by the frequently recurring floods in these rivers. In the neighborhood of the hills the rivers have cut deep channels through the gravel beds, showing in places an abrupt face of shingle 400 feet in height. These shingly bluffs decrease in height down the river, and in 10 miles have dwindled to about 30 feet; at the same time the river bed widens into a bare waste of shingle, over which the water flows in innumerable irregular, ever-shifting streams, sometimes dividing in wide and shallow reaches, again converging in narrow channels in which the river flows swift and deep. The abrupt terrace face now separates into minor ter-

races rising one above another, receding farther and farther from the watercourse. About 10 miles from the sea the banks almost disappear, the bed is choked with gravel, and is in many places raised to a higher level than the adjacent country.

The main line of railway along the east coast of the Middle Island traverses these plains. It crosses the Waimakariri on the tideway below the traveling gravels; a wide belt of drifting sand borders the river on each side, which is overflowed by every flood. On this margin the railway works used frequently to be washed away, but they are now rendered more secure.

The Rakaia is crossed by a piled timber bridge 1 mile in length, which has suffered many severe strains from the floods. Its approaches were often carried away until sufficiently raised and protected with rockwork groynes.

The Rangitata is the southernmost of the rivers that cross the Canterbury plains. After leaving the hills the northern side of the river is confined by high terraces for the greater part of its course to the sea. The southern banks are, however, low and broken, and the country to the southward falls rapidly away from the river. About 8 miles from the foot of the hills the river parts into two distinct groups of channels, known as the north and south branches, uniting again near the sea, and so forming the Rangitata Island.

The railway crosses the two channels of the river about 4 miles below the main parting. There are two railway bridges about 1 mile apart, each bridge having thirty two spans of 60 feet, with pilework piers. The main volume of water in the floods frequently changes from one branch to the other, being guided at the parting by the shifting beds of shingle that the river is continually moving forward.

The overflowing of the south branch during heavy floods in 1878 occasioned serious apprehensions for the railway works. At a point about 2 miles above the railway bridge a large overflow took place, which was extended and deepened by every successive freshet; the overflowing water concentrated in an old course and made a straight run for the sea, carrying away fences, railway banks, crops, and much valuable land.

It soon became evident that a few more floods would deepen this overflow, and allow the whole river to take a new course to the sea, so entailing the construction of another costly railway bridge, besides doing enormous damage to the country. Recognizing the necessity of checking the outbreak of the river, the Government approved plans submitted for the purpose, and authorized the estimated expenditure.

In designing these works the principal difficulties to be contended with were first, the absence of a base of operations (all the natural banks being so low, and the soil so friable as to be easily washed down by the flood water), and also the lack of any ordinary material for building. No rough stone was procurable nearer than 80 miles by rail, and 4 miles of cartage, which would have made it very costly. It was ultimately decided to make use of the material on the spot, viz., the boulders of the river bed. The regular diminution in size of the boulders and shingle down stream, so often remarked upon, is very observable in this river, and, owing probably to the considerable fall, the change is great within comparatively short distances.

About 8 miles above the railway the river bed is covered with boulders of from 2 to 3 cubic feet in size; at the breach, 4 miles lower down, the bed is chiefly composed of coarse shingle, but interspersed with numerous large boulders, 2 cubic feet being about the largest; another 4 miles lower down, viz., at the railway bridge, few boulders can be found more than ½ cubic foot in size. The appearance presented by shingly river beds after floods, giving the idea of rough hand-set pitching, is also very marked in this river bed. While the flood is running at full force the boulders, shingle, sand and silt are being carried forward at rates varying with the strength of the current and the weight of the different bodies propelled. They tumble along without any apparent order while the flood is at its height, but as the flood subsides and the propelling force of the current diminishes, the heavier stones begin to settle first, the smaller ones are carried lower down, and thus the process of sorting into sizes is accomplished. Again, as each stone in turn has nearly reached the limit of carriage by the water,

the process of "pitching" is carried on. Every stone which has one side flatter than its other surfaces tumbles along at random, until its flattest side happens to take a position inclined against the current, the dip having a particular angle of inclination with the horizon, and the strike parallel with the current, the angle being about 30°. As long as the flat side takes any other position the water has considerably more power to move the stone, either by lifting, turning or rolling it, than it has when it lies in the position described, for the force of the current is then deflected upward without having any tendency to move the stone, but rather tends to press it down and keep it steady; and thus each stone in turn becomes arrested in that particular position. This indicates the form and position of an obstruction to a running stream best calculated to withstand its force. It also follows from the tendency of the river to sort its stones into sizes, that if boulders are piled in any given part of a river bed, of an average weight exceeding the weight of the stones that the river has left there in its ordinary course, it will be beyond the power of the river to move the stones so placed.

The erection of earth embankments to confine the overflow of the South Rangitata was tried some years ago, but the river scoured its natural banks, and the ground on which the artificial embankments were built was carried away from under them.

To obtain more permanent results the work has to be placed in the river bed itself. Shingle-carrying rivers invariably run in successive shallows and falls. In one place the water concentrates into a comparatively narrow, deep torrent, with great fall, where it cuts away the bottom on one side; then again it widens out, slackens speed, and deposits the material excavated above in a wide and shallow beach. In such places it frequently parts into different channels, which may again unite lower down.

To ensure economy in protective works in these rivers it is requisite that the least possible area of the artificial embankments should be exposed to the current. The plan adopted was to form groynes having strong ends projecting into the current of the river, with connecting banks, inexpensively formed, to stand in still water under the protection of the groynes.

The scour and outbreak of the river which are sought to be prevented generally take place at the channels where the river is cutting the bank, and at that point it is most disadvantageous to attempt to cope with it. The stream to be checked or diverted must be traced up to the next shoal or parting above. At this point the velocity of the river is less, the depth of water is less, the possible rise of flood is less, the outfall of the water to be artificially intercepted will be the best, and therefore the tendency of the groyne to raise the superincumbent flood water will have the least effect. So far the shallowest part of the fall, where the stream separates and runs slowest, would be indicated as the best position for the groyne. But, on the other hand, if placed at that point the work would, when finished, stand in the full current of the flood and be exposed to scour along its foot.

The choice, then, lies on a line just below the top of the fall. A bank constructed across the funnel of the intercepted stream, just below the fall, will stand in still water not exposed to scour, while the water cut off from that channel will have a ready outfall down the neighboring channel. The embankment only requires sufficient height to overtop the highest flood to be perfectly safe. The space between the bank and the river current is soon filled up with gravel and sand, and the interstices between the stones in the work become completely grouted with silt. The bank having been made across the channel of the intercepted stream is turned up river on the shallow ground of the parting, and there the groyne is built which has to withstand all the force of the current of the river.

In building the groynes a pit was excavated in the river bed about 40 feet square and 20 feet deep. In this pit iron bark logs were placed at an angle of about 30°, the lower ends spread out like a fan, the upper ends being gathered together and bolted to a horizontal bar, like a ridge pole, at the level of the top of the embankment. A stout waling was then bolted along the feet of all the rakers, and a layer of the largest bould-

ers filled over the whole area, inside the timbers, up to the level of the waling; next a layer of stout manuka poles and fascines was laid at right angles to the walings, with ends projecting over the bottom waling; then another waling was bolted to the rakers holding down the ends of the poles and fascines, and another course of boulders followed, and so on up to the top. The whole of the pit outside the groyne was lastly filled up with the largest boulders procurable to the level of the original surface of the bed.

In order to divert all the flood water from the breach in the bank of the South Rangitata river, four separate channels had to be treated as above; the stop banks extended about ½ mile in length, with seven main protecting groynes and several minor ones, which were inserted to gather silt along the banks and keep off the current. The structure was begun at the lower end and continued up stream, as by so doing all intercepted water is finally disposed of. Works undertaken by commencing at the upper end often fail, because the water diverted above is accumulated in the last channel, and has all to be combated together at the last.

Progress was retarded by several severe floods, which carried away embankments before they or their groynes were finished. These were, however, rendered more substantial in consequence. A bank was completed about 14 feet in height, in a depth of about 8 feet of water. The protecting groyne was not finished when a flood came on. It washed away the upper 7 feet of the bank, and filled up the channel with large stones and boulders to the level of the lower 7 feet of the bank. For every yard in depth so washed off the bank, about 200 cubic yards of material were deposited in the channel. Had the bank stood, the upper side would have been occupied by degrees with light silt and sand, where now it is filled with heavy material.

The cost of the works was about £4,000; they were executed in eleven months, ending in August, 1879, by twenty-two men and eight horses. Each groyne cost on an average £200. The embankments contained 20,000 cubic yards of boulders, and have since stood several severe floods without damage.

The banks are capable of withstanding floods nearly up to their full height, and the groynes can be covered by floods without injury. The river bed has become somewhat piled up round all the groynes, and the pockets above are rapidly filling with silt. The main current of the river now runs on the opposite side.

It is not presumed that such works as these solve the problem of confining shingle rivers in their channels; but they prove a simple and effectual means of diverting a shingle-bearing river from any particular weak point. If a river were embanked throughout its course on both sides in this manner, it would doubtless eventually choke the bed assigned to it and overflow. This, however, will take place with more elaborate and costly protective works to an equal extent.

ON STEEL CASTINGS.*

By Mr. FRANK W. DICK.

From "The Engineer."

In this paper I propose to give a short description of the steel castings made at the Hallside Steel Works by the Terrenoire process. Although steel castings are known, appreciated, and largely used by many engineers, still it is a fact that at present a great number are either entirely unacquainted with them, or have conceived totally mistaken ideas about their nature and merits. Much of this misconception has no doubt arisen from the doubtful success which attended the crucible steel castings brought before the public some years ago.

The principal defects in these castings were hardness and want of solidity, and truly homogeneous metal was a rarity. It was found that by crucible casting

* Read before the Institution of Engineers and Shipbuilders in Scotland.

blowholes were less likely to be formed than in casting on a larger scale by the Siemens-Martin or Bessemer processes; hence, notwithstanding the expense and the many disadvantages inherent to the crucible method, it has been somewhat extensively applied, both in this country and on the Continent. In crucible steel castings a high percentage of carbon is employed to insure fluidity in casting, and the subsequent process of annealing is relied on to make them soft enough for working. In spite of every care these castings are often so hard as to be useless.

The accompanying honeycombed specimen shows what measure of success attended the first attempts at steel casting from the furnace. No matter how strong the material, it is perfectly evident that a casting such as this is quite unsuited for engineering purposes. A further objection which militated against the earlier steel castings was their want of homogeneousness. Hard spots were of frequent occurrence, surrounded by softer material. These spots appeared as lumps when the casting was turned or planed, and made it impossible to keep an edge on the cutting tool. But these objections are fast becoming things of the past, thanks to the Terrenoire process. It is now possible, and is a matter of everyday practice to get castings made of a material which is soft, strong, tough, and free from blowholes, which can be hammered cold or hot, which welds easily, and in fact, which behaves in every way like superior wrought iron, with this difference, that it is very much stronger than wrought iron. It may appear strange that a simple casting should possess toughness equal to or greater than iron which had been wrought; but it has been found from experiments made at Newton (as already noticed by Euverte) that the properties of a piece of steel (free from blowholes) depend entirely on its chemical composition and its molecular condition, and not on the manner in which that condition has been induced, so that if different means can be found to produce similar conditions in steel, the final result is not affected by the method employed. For casting such means are found in annealing and tempering, the effects of which will be noticed later on.

It has been already stated that the difficulty encountered in early attempts to make castings of Siemens-Martin or Bessemer metal was the formation of blowholes. In the Terrenoire process this fault is entirely remedied by the use of a silicide of iron and manganese. "The presence of a trace of silicon is found to have the singular effect of preventing that violent evolution of gas from fluid steel at the moment of solidification," which caused the objectionable unsoundness. In the fluid steel there is carbonate oxide in dissolution. During solidification this gas tends to escape, but is decomposed by the silicon and silica produced, and afterwards a silicate of iron, which would remain interspersed in the steel were it not that the presence of the manganese permits the formation of a very fusible silicate of iron and manganese which passes off into the slag. The metal when run into the mould remains perfectly quiet, and a sound casting is readily obtained, possessing a smooth skin and sharp edges.

A principal characteristic of this metal is its extreme toughness. On the table there are exhibited some turnings taken from a mill pinion, which argue the possession of that quality in the material in a high degree. There are also some bars shown which have been bent cold to an angle which few brands of wrought iron would reach. In one sense this toughness is a drawback—it renders the work of taking off the gates and runners one of extreme difficulty. It is of no use to attempt to "nick" them round and break them off, they must be turned or slotted off. The breaking strain varies according to the nature of the casting, and the subsequent treatment. Plain castings of some size may be made of very soft metal, while more intricate ones require to be made rather harder, but in no case is the metal really "hard," *i. e.*, too hard for tooling. In general the variation does not exceed six tons per square inch, and ranges from 29 to 35 tons per square inch. The extension varies from 36 to 12 per cent. in lengths of two inches, and from about 17 to 6 per cent. in lengths of eight inches parallel. Stronger qualities can be made, but any increase in strength is gained at the expense of toughness. The elastic limit I have

invariably found to range from $\frac{1}{2}$ to $\frac{3}{5}$ the breaking strain.

The ultimate character of the steel depends much on the treatment to which it is subjected after being cast. I do not refer to the practices of long-continued annealing and heating in contact with oxides of iron, often adopted in connection with crucible steel castings, but simply to the effects of heating and cooling in different ways. Before you are three samples of steel taken from the same casting. The first, which exhibits a largely crystalline fracture, shows the steel simply as it is cast; the second, which is much more compact in appearance, has been heated to a cherry red and cooled gradually; the third, which has a very close texture, has (after annealing) been again heated to a cherry red and cooled in oil. Beginning with the casting in its original state, the effect of reheating and cooling gradually is to greatly increase the toughness and the extension, to increase a little the breaking strain (except in very soft metals, in the case of which it is not much changed) and to decrease a little the proportion which the elastic limit bears to the breaking strain. By re-heating and dipping in oil the breaking strain and elastic limit are increased, the toughness and extension are diminished, and the metal is compacted. It will be noticed that the effect of dipping in oil appears to be analogous to that of hammering; much the same changes are induced. I have here two bars, one 1 inch square, cut from the same casting. One is annealed simply, the other is annealed and dipped in oil. They were tested transversely with 3 feet bearings. The annealed one took its first permanent set with a load of 0.4 tons applied midway between the supports, and finally sunk with a load of 0.7 ton. It has been bent through considerably more than a right angle, and is not broken. The one dipped in oil took its first permanent set with a load of 0.5 ton and sunk when loaded with 0.9 ton, breaking when bent through 90 deg. These bending tests corroborate the results of many tensile tests with regard to the increase of strength and decrease of toughness due to cooling in oil.

The art of steel founding is now so perfected that it is scarcely too much to say that anything which can be cast in cast iron can be cast in steel. The applications of steel are already almost innumerable. From it are made crank shafts, thrust shafts, connecting rods, eccentric rods, cross heads, guides, propeller blades and bosses, and even the nuts for them, gearing of all descriptions—the toothed wheels already cast ranging from a few pounds to as much as twelve tons in weight—carriage and wagon wheels, locomotive bogie centers, rolls and rolling mill gear, anchors, hydraulic cylinders, steam hammer faces and anvil blocks, and so on. It is seldom that a working stress of more than one ton per square inch is allowed to be put on cast iron. Hydraulic riveters of Hallside steel are in daily and satisfactory use under a working stress of 14 tons per square inch. Here, then, we have a material which can be moulded to any shape as readily as cast iron, and which is stronger and tougher than wrought iron. Moreover, like wrought iron it can be wrought under the hammer and welds with facility. It is almost unnecessary to point out the advantages which accrue from the possession of such a metal. The simple process of casting will, in numerous cases, displace the more difficult method of forging. In cases, also, where the engineer is tied to weight—as often instanced in marine engines—it is evident that the use of a material which is at least six or seven times stronger and more reliable than cast iron offers one means of securing lightness without the sacrifice of strength.

I will conclude with one or two examples of the relative durability of cast iron and steel. A cast iron worm in connection with the turning gear of one of the steam cranes in the foundry at Hallside was found to grind itself away in from two to three days. The steel worm by which it was replaced lasted eight or nine months. A driving pinion in the rail mill when of cast iron usually gave way in from one to three weeks and failed through breakage of the teeth. A steel pinion, made to replace one of these, was taken out at the end of two years' continuous work, and then only because the teeth were so much worn that they did not gear properly. Steel is invaluable in rolls which are much cut into by the sections they are intended

for. In plain rolls the surface lasts well. The method of chilling is not used, but the hardness can be increased by increasing the carbon. It should perhaps be mentioned that the shrinkage of steel castings is about 1 inch per foot.

HYDRAULIC MORTARS.

By DR. MICHAELIS, of Berlin.

From "The Building News."

If we admit the hypothesis of the formation of a hydro-silicate of lime, ignoring all accessory processes, we may thereby explain the nature of hydraulic induration. We do not intend to enter here into a full description of the hydro-silicate of lime and its properties, but shall merely examine two of its more salient features.

The calcic hydro-silicate which is found in all hydraulic limes, Puzzolana mortars, and Portland cements, can exist only under water or in a medium saturated with moisture; if exposed to the air, it loses, at ordinary temperatures, water of hydration, and its composition is thereby destroyed. If our hypothesis, that hydraulic induration is mainly owing to the formation of a hydro-silicate of lime, be correct, the above-mentioned property of this silicate will be observable in all hydraulic substances, including Portland cement. It has long been known, with respect to the "Santorin earth," that the mortar produced with this puzzolana (which is chiefly composed of pumice—volcanic lava), loses, in contact with the air, the cohesion it has attained under water. For some years, we have prosecuted investigations in this direction with regard to all kinds of hydraulic substances, and have conclusively established the fact that no cement can retain uninjured its cohesion, otherwise than by being kept in a damp medium.

It is obvious that this fact will be most apparent in the case of pure hydraulic mortars unmixed with sand or other aggregates. Every one will recollect having observed pure or rich hydraulic mortars which showed signs of incipient disintegration, in the form of hair-like cracks.

A second property of this hydro-silicate of lime is its behavior in every respect like a colloid. Its nature is similar to that of the hydrates of silica, alumina, magnesia, and lime (existing in quick lime). It presents the appearance of a swollen gelatinous body, with no tendency to crystallization; at least, in no case in which we have examined this silicate, have we been able to prove conclusively the presence of crystals. The hydro-silicate behaves like a mineral glue, and possesses all the cementitious properties of its constituents; during the process of desiccation, it becomes gradually more compact, and shows, up to a certain point, a constant progression in cohesive strength; finally, it surrenders its water of hydration, when the disintegration commences.

The less compact the hydraulic mortar, the more rapidly will this disintegration take place; the denser it is, the more capable will it show itself of withstanding it. Thus the pure hydro-silicate of lime is destroyed with rapidity; Santorin earth and Puzzolana mortars, within a short period; hydraulic lime and Roman cement more slowly; while, last of all to succumb, is Portland cement. Even this excellent material, if used neat or in large proportions and exposed to the air, cannot last out a single summer; after this period in our own climate (and this is much more notably the case in warm countries), it is found to be covered with a network of innumerable capillary cracks, which hitherto have been generally taken as a proof of imperfect manufacture or careless workmanship, and as being a sign, though an insignificant one, of a tendency to "blow." They are, however, in every case the natural and inevitable results of desiccation, and betoken the commencement of disintegration.

The above remarks will be sufficient to furnish our readers with the key to many hitherto unexplained phenomena; in order, however, to afford every one an opportunity of forming his own judg-

ment in the matter, we shall adduce from our investigations a few experiments which have a more especial bearing on the subject before us.

A sample of Portland cement (Wallsend brand) had lain for five years immersed in water, and during that period had given the following results (every number being the mean of at least ten breakings).*

Age 1	day,	223.73	lbs. per square inch.
" 2	"	245.05	" "
" 3	"	411.75	" "
" 4	"	496.67	" "
" 5	"	465.52	" "
" 6	"	509.62	" "
" 7	"	482.45	" "
" 1	month,	684.41	" "
" 3	"	752.97	" "
" 6	"	1002.29	" "
" 9	"	855.94	" "
" 1	year,	1149.79	" "
" 2	"	847.84	" "
" 3	"	808.30	" "
" 4	"	869.59	" "
" 5	"	962.33	" "

This cement was therefore of excellent quality; nevertheless briquettes of the same cement, which had lain under water for a period of five years, after being exposed to the air for ten weeks, at a temperature of 18° to 20° C. (64.4 to 68° F), showed a strength of only 433.8 lbs. per square inch.

The two portions of one of the strongest of the briquettes broken at 5 years (giving 1,024.1 lbs. per square inch) were dried over chloride of calcium, whereby the following decrease in weight was found to take place:

	Weight.	Loss of Weight.
Air dried,	203.300 gram.	
After 1 month,	185.527 "	17.773 gram.
" 2 "	185.300 "	0.227 "

Thereafter one portion of the briquette (*a*) was kept for five months over chloride of calcium, and then in the desiccator over sulphuric acid; the other portion (*b*) was wrapped in blotting paper, and placed aside in the laboratory.

These investigations were commenced in October, 1878; in both instances the decrease in weight was continuous, and was as follows:

	(*a*)	loss.	(*b*)	loss.
After 3 months,	99.322	—	85.981	—
" 4 "	99.128	0.194	85.990	—
" 5 "	98.724	0.344	85.775	0.209
" 6 "	97.945	0.829	85.703	0.072
" 7 "	97.802	0.143	85.658	0.045
" 8 "	97.570	0.282	85.597	0.059
" 9 "	97.290	0.280	85.495	0.104
" 10 "	—	—	85.353	0.142
" 11 "	—	—	85.165	0.188
" 12 "	95.292	1.998	84.892	0.263
" 13 "	95.042	0.250	84.755	0.137
" 14 "	94.463	0.579	84.260	0.495
" 15 "	94.106	0.357	84.064	0.196
" 16 "	93.507	0.599	84.138	—
" 17 "	—	—	83.437	0.627

The loss has hitherto been constant; the same investigations are being continued.

With the excellent "Stern" cement a series of tests, to extend over a period of ten years, was commenced in January, 1876, with a view to establishing the relative strength of cement tested in a dry and wet condition. The wet briquettes were tested immediately on being taken from the water, those to be broken dry were removed from the water 14 days before testing. While testing the briquettes broken after 30 days (in February) and also those from the first to the fourth year (broken in January) the room was heated.

Age.	Broken Wet.	Broken Dry.
7 days,	777.3 lbs. per sq. in.	—
30 "	844.4 "	707.0 lbs. pr. sq. in.
90 "	958.9 "	902.9 "
180 "	912.1 "	730.9 "
1 year,	925.1 "	623.8 "
2 "	997.7 "	600.9 "
3 "	685.7 "	509.9 "
4 "	947.3 "	396.8 "

Among the numerous tests (over 80,000) which have been carried out in our laboratory, those made neat cement, lime, and puzzolana mortars, which were kept exposed to the air, invariably showed at advanced age signs of incipient disintegration more or less distinct, unless care was taken that the atmosphere in their vicinity was kept saturated with moisture.

The fracture of a cement, injured through desiccation, is so characteristic that the progress of disintegration or loss of strength may be recognized with ease. The appearance which any pure hydraulic mortar presents, if broken at a certain age, is invariably of a "shelly"

* We are of opinion (See also "Zur Beurtheilung des Portland Cements," Polytechnische Buchhandlung. A. Seydel, Berlin, 1876. that the decrease in tensile strength after the first year is merely apparent, and that it is due to a change in the molecular structure. In course of time the structure of cement gradually approaches in appearance that of porcelain; its elasticity diminishes, but its resistance to pressure increases, or the relation between the tensile and the crushing strength becomes altered in favor of the latter, the cement becoming more brittle.

character; a cement which has been injured by desiccation shows, on the contrary, a fracture of a more serrated nature.

Investigations with the object of ascertaining the degree of humidity of the atmosphere, beyond which hydraulic mortars retain their water of hydration, are at present in course of prosecution. By another series of tests we are endeavoring to establish the extent to which mixtures of hydraulic materials with sand, or other aggregates, are capable of withstanding the destructive effects of desiccation.

In analogy with the behavior of quicklime, and in accordance with the colloidal nature of the calcic hydro-silicate, the contraction is less injurious in its effects the poorer the mortar.

We have endeavored to show how the hydro-silicate of lime existing in hardened cement becomes, by continued separation of its water, gradually more dense, and, although in its separate particles becoming harder, is eventually destroyed through the fissures produced by contraction, which then become the cause of the total disintegration of the mass, under the changing influences of heat and cold, and more particularly of frost.

If it be true that the destruction of cement is due merely to contraction, causing interruption of continuity of the mass—in short, to those capillary fissures —it must follow that the well-known means for preventing contraction, especially the admixture of sand, will enable cement to escape these disastrous results.

It is understood that we speak here only of cements of unexceptionable quality, and their deterioration when exposed to the action of the atmosphere. The disintegration of cement mortars kept under water in a moist condition arises from imperfections in the cement, in most cases from actual "blowing," and in such instances the fissures produced are appearance of a totally different character.

If briquettes of neat cement and of cement and sand mixtures, which have undergone the hardening process for a considerable period immersed in water, and are perfectly intact, and have attained a high degree of strength, be exposed for a lengthened period to a process of desiccation, either in the desiccator over sulphuric acid or chloride of calcium, or in the atmosphere at a temperature between 60° and 120°, C. (140° to 248° F.), in every case the neat cement will be observed eventually to be covered with fine capillary cracks. The larger the size of the briquette the more rapidly and distinctly will these cracks make themselves apparent. In the case of tensional briquettes, even in the small one-inch section fiddle or wedge-shaped pattern, considerable cracks may be observed in the direction of the long axis of the briquette. The strength is found to be affected more or less, according as these cracks take place more or less nearly at right angles to the line of tension. Even very distinct cracks, when in the direction of the strain, exert little or no influence on the tensile strength.

In many cases no sign of capillary cracks can be discovered, even on a very close external examination of such dried briquettes; the characteristic serrated fracture on breaking reveals, however, at once, the latent pressure, so to speak, of contraction.

In the case of cement and sand mixtures, the writer has not, for a long time, observed any such phenomena when the cement was of good quality, and mixed with not less than two parts of sand; even with mixtures of 1 : 1, if worked up sufficiently stiffly, cracks are very seldom apparent in small briquettes.

The larger the size of the object which is prepared from cement mortar, and the greater the strain to which it will be subjected, the smaller should be the proportion of cement used. On this account also, it is in the highest degree requisite that cement be ground much more finely than has hitherto been customary. If, for example, a manufacturer of artificial stone employs 1 part of cement, ground to the ordinary degree of fineness, with 2 or 3 parts of sand, he might, with a more finely-ground cement, such as would pass through a sieve with 32,000 meshes per square inch and leave no residue, use 5 or 6 parts of sand; the article produced would attain the same strength after the same length of time as that prepared with a much larger proportion of coarsely-ground cement, and would, at the same time, exhibit a much better appearance and remain free from capillary cracks.

In order to study the effect of desiccation on mixtures of cement and sand, we have carried out, among others, the following series of tests, the briquettes employed being of 5 square centimeters sectional area :

1. The same cement as that of which the strength, up to the age four years, is given above, and which was thin, was tested neat, in the one case direct from the water, in the other, after lying 14 days exposed to the air, was made up with one, two, three, and four parts by weight of sand and tested, in the case of those under "A" immediately on being removed from the water, those under "B" being permitted to remain 28 days exposed to atmosphere.

The mean, in each case, of 10 briquettes, furnished the following results in lbs. per square inch :

	1 : 1		1 : 2		1 : 3		1 : 4	
Age	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*
180 days	603.1	754.5	462.3	637.2	347.0	583.1	285.9	450.8
1 year	635.9	775.2	487.7	611.6	368.8	458.1	302.8	406.6

Thus it will be observed that in no case did a decrease in strength take place through the briquettes being dried before breaking; but, on the contrary, a considerable advance in strength, and that from causes of which I shall hereafter treat.

2. Briquettes of one part cement and one part sand, which had been undergoing induration under water for a period of 3½ years, were broken as follows:

a. Directly on removal from the water.

b. After four weeks' air drying.

c. After 27 days' air drying; the briquettes were then re-immersed in water: tested directly from the water.

d. After 21 days' air drying, then seven days re-immersion in water: tested directly from the water.

e. Seven days' drying at 130° to 140° C. (266° to 284° F.).

f. Seven days' drying at 130° to 140° C. (266° to 284° F.). Then one day re-immersed in water: tested directly from the water.

g. Seven days' drying at 130° to 140° C. (266 to 284° F.). Then seven days re-immersed in water: tested directly from the water.

The following are the results, each number being the mean of ten breakings, in lbs. per square inch :

a	*b*	*c*	*d*	*e*	*f*	*g*
411.6	672.8	484.3	480.0	588.1	428.1	374.1

It will be observed that *b* to *g* inclusive, which were subjected to a process of desiccation, have suffered no diminution in strength (the insignificant variation between *a* and *g* is such as occurs between briquettes treated identically); it is well known that a certain slight increase in strength is always occasioned by the formation of carbonate of lime; this, however, may be left entirely out of account in view of the fact that all cements, sand, mortars, as also all common bricks (capable of absorbing a considerable amount of water) porous sandstones, &c., present, in the dry state, greater resistance to the separation of their molecules.

The series of tests, *c*, *d*, *f*, and *g* afford ample proof of this.

3. A cement mortar of one part of cement and five parts of sand, showed, after 20 months' hardening under water, an average strength of 349.2lbs. per square inch. Several of the briquettes were taken out of water, after a period of 12 months, and immediately placed in a desiccator; they were then dried for eight months over sulphuric acid, thus securing the elimination of all influence of carbonic acid. These briquettes broke, after 20 months, at an average strain of 490.3 lbs. per square inch.

These experiments prove, in a conclusive manner, that mixtures of cement and sand do not become disintegrated like neat cement mortar; the addition of the sand removing effectually any tendency to contraction, and the consequent formation of fissures; thus, the continuity of the mass is nowhere interrupted. On the other hand, we may safely conclude that the presence of these contraction fissures is the sole cause of the disintegration of pure and rich cement mortars when exposed to the action of the air.

The foregoing remarks will readily explain the complete fiasco which artificial stone has always been, when pure cement, or large proportions of the same, have been used.

ON LIGHT RAILWAY LOCOMOTIVES.

By HERR VON BORRIES.

Abstracts of Institution of Civil Engineers.

This is a continuation of an article already abstracted.* Referring to the table of leading dimensions in that article, the author states that the figures given for heating surface, grate surface, and capacity for water, are not to be considered as the greatest possible, and as capable of no further improvement; they are rather figures which can be and ought to be attained under all circumstances. At the same time increase in such particulars—*e. g.*, in size of boiler—is not the first consideration in light railway engines; for these the point of chief importance is security against damage of all kinds, which can only be attained by ample strength in constructive parts. In capacity of water tanks and coal bunkers, however, there is more room for improvement, and it is considered that with the best construction of engines, having the leading dimensions and weight given in that table, the water tanks may hold 0.16, 0.14, and 0.12 cubic meter per ton weight of engine, according to the gauge, while the coal bunkers may hold 0.05 to 0.04 cubic meter per ton weight.

On the other hand, the haulage weights given in the second table are to be taken as the maximum which can be attained in favorable weather; wind, rain, &c., will reduce the amount, and it will be better to take 90 to 95 per cent. of the figures given as the average for practice.

The author then proceeds to discuss the application of the compound system to light railway engines, which he considers to be necessary, if the pressure is to be raised above 150 lbs. per square inch. Its special recommendation for light railways is the saving in fuel, which is here of great importance, and compound engines on the author's system are not really more complicated than the ordinary kind. The compound engine, if built to the leading dimensions of Table I., will be somewhat heavier on account of the larger cylinders, &c.; but, since it will use less water and coal, the necessary reduction in weight may be effected by reducing the space for these, the boiler, &c., being kept as before. The cut-off in the small cylinder should not be at more than half stroke, giving 1 to 0.26, or about 4 to 1, as the grade of expansion in the two cylinders jointly; which gives a mean pressure of about 90 lbs. on the large piston. The volume of the large cylinder will then be about $2\frac{1}{4}$ times the volume of the cylinder specified in the table of dimensions, and as this is too large, the stroke must be lengthened. This leads to the following table:

Cylinder Dimensions, Compound Engines for Light Railways.

	(*a*) 4 feet $8\frac{1}{2}$ inch gauge.		(*b*) 3 feet $3\frac{3}{8}$ inch gauge.		(*c*) 2 feet $5\frac{1}{2}$ inch gauge.	
Number of axles	2	3	2	3	2	3
Weight of engine, loaded, tons	18	27	15	$22\frac{1}{2}$	$7\frac{1}{2}$	$11\frac{1}{3}$
Diameter of small cylinder, inches	11.4	13.8	10.2	12.6	7.5	9.1
" large " "	15.7	18.9	14.2	17.3	10.2	12.6
Stroke, "	22.0	22.0	18.1	18.1	13.4	13.4
Wheel diameter, "	38.6	38.6	31.5	31.5	23.6	23.6

The adhesion-weight, and therefore the power of these engines, is the same as those of the corresponding type in the former tables.

The author next considers locomotives in which the adhesion-weight is artificial-

* *Vide* Minutes of Proceedings Inst. C.E., vol. lxiii. p. 392.

ly increased; the object of course being to enable the engine to haul a greater train load on a given incline than that shown in the second table. For this purpose part of the train load is placed on the engine itself, and thus becomes available by adhesion for hauling the remainder. As the capability of the boiler cannot be further increased, the speed on any incline will be lessened in proportion to the increase of the adhesion. The limit here will be when the whole train-weight is placed on the engine, in which case it could theoretically surmount a gradient of 1 in 7½. It is another question whether this plan is advisable, and such applications have at best a very limited field. The ordinary plan is to place upon the engine the space for passengers and luggage, leaving goods and minerals to be drawn by separate wagons. Since lines with steep gradients have commonly sharp curves, the steam-carriage is generally composed of a body resting on two bogies. The engine rests on the front bogie, then comes the luggage compartment, and behind this the passenger compartments. It is best to fix the boiler rigidly to the front bogie, but to unite the carriage part to it by a movable attachment, so that the engine may be separated from it when going into the shop for repairs. All the steam-carriages hitherto built have an engine only on the front bogie, but there is no reason why there should not be one on the hind bogie also. It would then appear specially advisable to adopt Mallet's compound arrangement, using the front bogie for the small and the hind for the large cylinder, the intermediate pipe serving as a receiver. The author, however, considers this arrangement too complicated and expensive, entailing a large cost in fuel and repairs. He would prefer a rack engine where the gradient was so steep as to suggest this arrangement. It may be assumed that for passenger traffic the speed on the steepest incline should not be less than six kilometers an hour, and, since the engine by itself would go at double that speed, there is no advantage in raising the adhesion weight beyond twice that of the engine. The front bogie will then carry two-thirds of the total weight, and the hind bogie one-third.

To consider the advantages and disadvantages of the steam-carriage system, it should be compared with a separate engine doing the same work. It will then be seen that the advantage of the former lies merely in its giving a lighter and cheaper engine; while the disadvantages are the reduced speed on the gradients, the greater wear on the carriage, and the increased difficulty in turning and shunting. Hence it should only be used where the gradients are steep, say above 1 in 30, and its field is probably limited. The dimensions, &c., will be similar to those in Table I., except that the boiler will be about half as large. It appears that two men are sufficient to manage such a carriage, but both must be qualified to drive, and there must be a door between the engine and the passenger compartment.

The author next considers the type of engine required for working local traffic on main lines in omnibus trains, as they are called. Although these engines are not for light railways, they are practically of similar construction, since the object is to work the local traffic in the very cheapest manner, and separate from the through traffic. The heavy engines and carriages, suited to the high speed, &c., of the through traffic, are out of place in local traffic. For local passengers cheapness and frequency of trains are the great recommendations, and the rolling stock must be altered accordingly. The speed on the level may be taken at 30 to 40 kilometers per hour. There are two cases to be considered according as the traffic is (1) between two ordinary stations; (2) suburban traffic in large towns. For the first the author recommends the trains to consist of an engine, a mail and luggage van, a mixed second and third-class carriage, and a fourth-class carriage; in the second case mixed second and third-class carriages of special construction are recommended. In both there should be continuous brakes, and communication throughout the length of the train.

Steam-carriages have been applied for this purpose, as well as for light railways. The advantage is that they save the buffing and draw gear, amounting to a weight of 500 kilogrammes per carriage. On the other hand a steam carriage cannot go backwards, but must be turned at each terminus, and the dead weight is

always the same, as a carriage cannot be detached. Again the detached carriages generally run double the distance of an engine, and this advantage cannot be obtained with a steam carriage. For the sake of engine repairs the carriage and engine part are generally made separable, but this entails extra complication.

It thus appears there are few circumstances in which the steam carriages are to be preferred. A separate carriage on a main line will weigh about 8 tons, and will acommodate 40 persons, if constructed as lightly as possible. If then the maximum number of passengers per train is less than 40, the steam carriage may be preferable, but it should not have more than four wheels.

It was stated before that an ordinary light railway engine will make full use of its adhesion only at a speed of 12 kilometers (7 miles) per hour. For a local traffic engine this may be raised to 15 kilometers (9 miles) per hour by means of a higher evaporative duty. But this speed is far too low for local traffic, even on the steepest gradients. Hence even the separate engine can never use its whole adhesion weight, far less does it need any increase of it, and this seems to settle the question against the steam carriage.

The construction of separate locomotives need, therefore, alone be considered. The weight of well-constructed tank locomotives for a standard gauge is given by the formula $5+0.3$ H tons, where H is the heating surface in square meters. This formula is derived from the experience of Krauss & Co. and Herschel & Son, but applies to this case, where an engine of the greatest power is wanted, more than to light railways, where cheapness and durability are the first considerations. Taking the best construction, which is to have two driving wheels only, carrying 0.6 of the total load, the power of the engine is represented by $138\times0.6\times(5+0.3\,\mathrm{H})\times1{,}000\times v$, where v is the speed in kilometers per hour. On the other hand the total performance of the steam per hour, allowing 30 kilogrammes to be evaporated per hour, is given by $\frac{3{,}100\times30\,\mathrm{H}}{1{,}065}$ taking the engine friction at 6.5 per cent. Equating these two together results in a formula for v which gives:

Heating surface..sq. mtrs.,	10	20	30	40	50
Total weight.........tons,	8	11	14	17	20
Speed, kilometers, pr. hour,	4	20	24	26	28

Since these velocities are as low as would be admissible on a line with gradients of 1 in 100, it follows that two driving wheels are sufficient, and this is confirmed by most of the engines for such lines being so built. Where the gradients are above 1 in 100 the construction would be somewhat different. The advantage of having no coupling rods is that the front axle may be put before the cylinder, and the hind axle far back, so that a good wheel base can be obtained with a short boiler. The following table gives the leading conditions for five classes of engines for local traffic:

LOCAL TRAFFIC ENGINES.

Weight loaded.....................tons.	8	11	14	17	20
Adhesion weight.................... " .	4.8	6.6	8.4	10.2	12
Heating surface...............sq. meters.	10	20	30	40	50
Grate " .... " .	0.2	0.4	0.6	0.8	1
Steam pressure...............atmospheres.	12	12	12	12	12
Diameter of driving wheels..........mm.	980	980	1,130	1,130	1,330
" cylinders.............. " .	180	200	240	260	280
Stroke............................. " .	300	360	400	400	500
Contents of tank.............cub. meters.	1.3	1.8	2.2	2.7	3.2
" coal bunkers..... " .	0.48	0.66	0.84	1.02	1.2
Wheel base.......................mm.	2,500	3,000	3,300	3,500	3,800
Tractive force (without friction).....kilog.	600	880	1,120	1,360	1,600
Minimum speed......kilometers per hour.	15	20	24	26	28
Compound engines, stroke...........mm.	340	400	440	440	500
" " diameter of small cylinder .... " .	180	200	240	260	290
Compound engines, diameter of large cylinder .... " .	250	280	330	360	400

THEORY OF THE ACTION OF RAILWAY BRAKES.

By E. PERRON.

From "Organ fur die Fortschritte des Eisenbahnwesens," for Abstracts of the Institution of Civil Engineers.

The author first gives the equations for a heavy wheel moving forward on a rough horizontal plane, and at the same time turning round its axis with given angular velocity, and points out that if this given angular velocity be not originally such that the linear velocity of the periphery equals the horizontal velocity of the wheel (in other words, such that the wheel rolls on the plane) the effect of friction will speedily cause it to assume that particular value. He then takes the actual case of a railway vehicle acted on by a brake, and points out that the effect of the frictional resistance of the brake block is to produce an equal and opposite frictional resistance between the rail and the wheel, and that it is this latter variable resistance which is the real external force tending to stop the vehicle; the brake-block friction must be treated as an internal force. He then forms the ordinary equations for expressing the linear and angular acceleration of the wheel in terms of the applied forces, and from them deduces two expressions for fX, the frictional resistance between brake block and wheel, one of them in terms of the time, the other in terms of the distance which is passed over by the wheel from the first application of the brake until it comes to rest. (These expressions, however, assume that the co-efficient of friction between brake block and wheel is always the same, and will require correction in order to take account of the fact now established, that this co-efficient varies with the speed, and is therefore never the same at any two moments during a stop.) The expressions for X show that, when the wheel is stopping, the frictional resistance of the block is greater than that of the rail by an amount which is, in fact, the force expended at each moment in destroying the *vis viva* of rotation in the wheel. This excess, however, is insignificant, amounting, in the case of an ordinary railway wheel and axle, to about 20 lbs.

The maximum effect of a brake is attained when the rail friction which it calls into play is the utmost which the rail is capable of exerting, *i. e.*, is equal to the weight on the rail multiplied by the co-efficient of friction between rail and wheel. Any greater amount of brake friction can only be expended in stopping the rotation of the wheel, *i. e.*, in causing it to slide. The value of this maximum pressure is easily obtained from the general equations. The high value of this maximum appears to conflict with the well-known fact that even the heavily-loaded wheels of a tender can often be skidded by means of ordinary hand brakes, applied by a single man. This the author considers to arise from two causes (1) the great mechanical advantage given by the screw gear of an ordinary hand brake, amounting to about 60 to 1; (2) the fact that the surface acted on between wheel and block is very much larger than that acted on between wheel and rail, and that according to Coulomb the total friction for a given pressure increases with the area.

The author then goes on to consider continuous brakes, and lays down the five following essential requisites for a good brake:

(1) Before everything else, simplicity of construction, combined with lightness and mobility in the parts, for rapid working.

(2) The brake to be controlled either by driver or guards.

(3) The action to be automatic, so that in case of accident the brakes shall put themselves on.

(4) The brake to be available even when the train is not completely made up.

(5) The working power to be always ready, and easily increased or diminished, so that it may be used for controlling the train in ordinary running, as well as for stopping it altogether.

The author finally discusses the Heberlein brake, and observes that while it is

seen at once to fulfill the first four conditions, it is otherwise with the last, since it seems impossible that a comparatively small friction roller should be able to produce the great pressure on the blocks requisite to elicit their maximum effect. He therefore gives a theoretical investigation to show that by varying the angle which the hanger of the friction roller makes with the horizontal, a strain of any required amount can be brought on the chains which actuate the brake blocks.

THE CONSTRUCTION AND WORKING OF LIGHT RAILWAYS ON COMMON ROADS.

By HERR BURESCH.

Abstracts of Institution of Civil Engineers.

The conditions to be satisfied, if a road is to be utilized for a light railway, are (1) that it should be wide enough for both kinds of traffic, (2) that the gradients, &c., should be suitable for a railway of the kind intended, and (3) that the direction of the road should suit the traffic to be conveyed on the railway, without making too great a circuit. As to (1), if the road is to be laid with a railway of normal gauge, requiring 13 feet width to itself, the total width between the ditches should not be less than 27 feet, and had better be 33 feet. If the gauge is $\frac{3}{4}$ meter or 2 feet 6 inches, the minimum width may be 20 feet. As to (2), the gradients should be as light, and the curves as few and easy as possible, in order that the engines may not be too heavy.

The most important question is the saving which will be effected by the utilization of the road. To answer this it is necessary to estimate, under its various heads, the cost of a light railway not laid on a road, but taken from point to point by the easiest route, and then to consider how far each item will be reduced by laying it on an existing road. It is assumed that no special expenses, such as paving the railway for horses, are required, and that the general conditions are the average ones of an ordinary hilly country. The various items of cost and reductions, due to using the road, will then be about as follows, (see Table, next page,) each given as a percentage of the total cost in the case of a light railway.

It thus appears that the saving by use of the road may be put at one-third, of course on the assumption that the railway pays nothing for the occupation of the road. Financially, therefore, the advantage is great; it remains to consider the other elements of the question. The advantages are as follows: (1) The arrangement having once been made with the proprietors of the road, the long and costly proceedings for the purchase of land are avoided, and the line being laid on a public road no private rights are interfered with. (2) The preliminary works are much lightened, inasmuch as the trace of the railway is already fixed almost throughout, and the bridges and culverts are arranged. (3) The materials required can be cheaply and easily brought to the spot by the road. (4) The existence of the road makes the maintenance of the line cheaper and easier from the first, and the old roadway forms a better foundation than new earthwork can. (5) The watching and cleaning of the line is cheapened by using the same set of men for road and railway. (6) As the road passes right through the towns and villages on the route, the stations can be placed where most convenient for the public, and for the railway. (7) Branches to works, yards, &c., can be made at the least possible cost, and the station yards can thus be simplified.

Whilst these advantages are undoubtedly great, the following disadvantages are also to be considered:

(1) The unfavorable nature, in general, of the gradients and curves, especially on old roads and in hilly countries, seriously diminishes the advantage of using the road, and sometimes wholly destroys it. A saving in construction is dearly purchased if disproportionately heavy engines have to be employed for work-

Item of cost.	Cost for railway.	Saving by use of road.
	Pr. ct.	Pr. ct.
A. Purchase of land (The 5 per cent. will be spent in necessary diversions at villages, at steep inclines, and at sharp curves, for stations, sidings, &c.)	13	8
B. Earthwork and ballasting (It is assumed that sharp gradients and curves are got over by diversions from the road, so as not to increase unduly the cost of working.)	14	8
C. Bridges and culverts (It is assumed that the existing works can be utilized without much enlargement.)	8	6
D. Permanent way (Here there can be no saving, but probably the reverse, since wherever the railway crosses the road paving and tramway rails must be used.)	27	0
E. Track laying (At crossings, &c., some expense for maintenance must always be expected.)	2	1
F. Fencing (It is assumed that there will be no fence between the road and the railway; but some fencing will always be required at diversions, &c.)	2	1
G. Signals	1	0
H. Buildings (It is supposed that for stations, &c., existing houses will mainly be utilized.)	11	5
I. Rolling stock (Here there will be no saving, but rather an increase, if the gradients are more severe and require heavier engines.)	12	0
K. General expenses (A line laid on the road will not require so much allowance as usual for contingencies.)	10	4
Total	100	33

ing. The modern use of steel rails does not remove this difficulty. The cost of working increases more rapidly than the weight of the motor, because of the small load which the latter is able to haul on steep inclines. Economical working is only possible with favorable gradients and curves. If this point is neglected, especially on lines with small traffic, the expenses are likely to exceed the receipts. Should these unfavorable conditions occur only at a few points in the road, they should be avoided by diversions or circuits. Where the road passes through villages, very sharp curves should be avoided, even at the expense of crossing the road, a process which is rendered easy by the use of sunken tram rails. Steep gradients, if short, or rapid undulations, are not of much importance; since, with the slow speed and light trains of such railways, they can be easily surmounted.

(2) The danger of setting fire to buildings, &c., should be carefully considered before the railway is commenced.

(3) The same applies to fencing between the railway and the road. If this is required, it would probably be better to lay an independent line.

(4) The speed on a common road must be lower than is usual with light railways. Although the road traffic commonly falls off when the railway is opened, this may not happen if the road is largely used for driving cattle, and other agricultural purposes. In such cases it is generally required that the exhaust shall not be visible or audible, and often that the train shall stop when passing cattle, &c. The difficulty of seeing far ahead on a common road also prevents a rapid speed. Assuming 12 miles an hour as the normal speed for a light railway, that on a common road will not exceed 9, which is not much greater than that of ordinary carriages.

(5) The risk of accident to men and cattle is of course much greater than on a railway.

(6) Opposition may be expected from the public who use the road, and who, not understanding the advantages of the railway, resent its intrusion. This is sure to take the form of petty annoyances, which may seriously hinder the success of the line.

It should be added that an intermediate course may often be possible, *e.g.*, to lay the line on the other side of the road fence, or immediately above the ditch; or sometimes in one of these positions and sometimes on the road itself.

It thus appears that the question of laying a light railway on a road must be decided by a careful balancing of the *pros* and *cons.* If the need of the railway is urgent, and the capital for an ordinary line hard to procure, the road should receive the preference. If the embankments of the ordinary line could

be used for reclaiming waste lands, as may often be the case in marshy valleys, this would be an argument in its favor, and similarly if the laying of the line upon the road met with great opposition in the district.

In Part II., p. 52, follow two supplements to the above by Herr Tull and Herr Alken, co-referees with Herr Buresch. The former remarks that several Prussian provinces have laid down conditions as to the laying of railways on common roads. Under these regulations the top of the rails must be level with the surface of the road, and gradients steeper than 1 in 25 cannot be utilized. It is, however, allowable to make the formation level of the railway higher or lower than that of the road if required. The ordinary high roads of 33 feet total breadth, of which 21 feet are paved, are not considered wide enough for railways of standard gauge. This might well be relaxed on many roads where the traffic is small. It is further ordered that engines working on such lines should be fitted with the best known appliances for noiseless working, and for preventing the escape of smoke and steam, and should have the mechanism hidden from view. This would seem necessary only where the road is bordered by buildings, and in such parts the railway will generally take another course. On the open road such restrictions seem out of place, since even horses, as is well known, get quickly accustomed to ordinary locomotives. It will much hinder the use of such railways by main lines, with which they may communicate. Lastly, the Railway Company has to place caution money in the hands of the owners of the road, to be used in taking up the railway should this ever become necessary. The amount is made proportional to the total capital of the railway, whereas it should be proportional to the cost of the permanent way alone. The conditions on the whole are far too favorable to the owners of the road, who should be simply considered in the same relation as the owners of property through which a line passes, and for the same reason, viz., that the construction of such lines is to the public interest.

Herr Alken concurs in the view that the relations between road and railway should be settled by law, and thinks the formation of such railways, whilst of great moment to the public and to the main lines, might also be made of service to the owners of the road. He suggests that the repair and working of the road and railway should be placed under a common Board, who should also collect the dues on both, and divide them in some fixed proportion. There would thus result a considerable saving in wages, a simplification of arrangements, avoidance of all friction and competition between the two bodies, and combined action towards customers and the public. Many of the restrictions placed on the railway might then be removed, and compromises come to upon others.

THE DUPUY DIRECT PROCESS.

The attention of the scientist as well as the practical iron maker, has long been directed to the very desirable results of producing malleable iron direct from the ore without the necessity of first melting it into pig iron, and then puddling the pig. Malleable iron can be thus made, and has been so produced, to a limited extent, in India, and other countries for many years; but, we believe, until the invention of the Dupuy process, no practical commercial success had been achieved, by which any considerable quantities of malleable iron could be turned out. The process of Mr. C. M. Dupuy is so simple, and yet so certain that it can hardly fail to engage the attention of practical ironworkers as an economy which it is impossible to ignore. We therefore propose to place before our readers the latest improvements in this process. Reduced to a simple statement of plain facts, it consists in grinding the iron ores, or other iron-bearing materials, such as tap cinder and droppings from puddling furnaces, iron and steel scale, blue billy (or purple ore) into the condition of a coarse sand, and mixing with

the pulverized material from 15 to 18 per cent. of coal dust, together with a certain quantity of aluminous clay, lime, and salt. These pulverized substances are intimately mixed together in a mortar mill, or similar machine, and in a thick moist condition. From thence they are taken to a machine similar to that used in making drain pipes, where they are pressed into pipes or moulds of about 16 inches in length by 7 to 8 inches diameter, and having walls from 2 to 2¼ inches think. These pipes, when thoroughly compressed, are taken from the machine, and charged on their ends into a heating furnace; being spaced about 3 or 4 inches apart on the furnace bottom. The heat is properly applied, and in about two hours the metal in the mixture is brought to nature, and can be balled, hammered into blooms, and rolled directly into bars, all in the same heat, and with the limits of waste not exceeding 15 to 20 per cent. of the metallic value of the iron which the ores or iron-bearing material contains.

The malleable iron thus produced has been found to be equal, if not superior to, bar iron made by the puddling process, whilst the cost of first reducing the ore into pig iron is thus saved. By means of the aluminous clay, lime and salt (applied in proper proportions and depending on the analysis showing the constituent elements of the ores) the phosphorus, sulphur and other impurities are so carried off in the slag, that a greater purity of the iron is secured than by the ordinary method of puddling. We are informed that the most recent working with this process shows that from 3 tons of puddle tap cinder containing 17.710 of silicon and 1.960 of phosphorus, one ton of bar iron was produced, which yielded an analysis 0.26 of silicon and 0.38 of phosphorus. This charge was reduced and rolled into bar within three hours and all in one heat. With old Bed Champlain ore largely carrying phosphorus, which was reduced and rolled within the same time, the analysis of the bar showed only 0.16 of phosphorus. The utilization of tap cinder by this process would appear to be an assured fact.

The economy of the process is shown by its simplicity, and the advantages derivable are stated to be as follows: In the first place all expensive plant is avoided, as the reducing furnaces, even where specially constructed (and which may not always be necessary) do not exceed a cost of £300 each. Such furnaces are capable of yielding from 4 to 5 tons of malleable iron daily when worked by two men. Two furnaces can be worked at the same time, and with much less labor than by puddling. The grinding, mixing and moulding machinery are quite inexpensive. The entire saving of the cost of first reducing the ore into pig is thus effected. The rapidity with which malleable iron is formed proves a great saving of fuel in the reduction, and necessarily in the cost of the bar iron. Under this process, by which the intimate commingling of the various atoms of the mixture is secured, the iron of the ore is stated to be dephosphorized, desulphurized and desiliconized in the reduction, and thus the purity of the malleable iron produced makes it eminently suited for the manufacture of steel by the crucible as well as the open hearth or Siemens-Martin process, whilst the cost of the iron in its malleable state is, under favorable conditions, said to be even below that of the Bessemer pig iron used in many of the open-hearth steel furnaces. In using the tap cinder and droppings from puddling furnaces, as also the scale from rolls and hammers, a great saving results to mill owners, as from each three tons or less of these comparatively waste products, 1 ton of good bar iron can be obtained, at a cost of about two-thirds of the ordinary selling price of the puddled bar.

It is worthy of remark that by these late improvements Mr. Dupuy entirely does away with the use of the sheet iron canisters formerly deemed by him absolutely necessary to preserve the iron ore from the waste of oxydization. This important item of expense being saved (some 15s. to 20s. in the cost of each ton of bar iron produced) and the time necessary for the reduction in the furnace being now shortened one-half, mill owners will no doubt readily appreciate the value of a system which will enable them at a very trifling outlay to work up into profitable bar iron a material heretofore deemed by them almost as a waste product, if not even a serious charge upon their profits by its rapid accumula-

tion. The Dupuy process is in active operation in the United States of America, and we have recently examined some excellent specimens of iron manufactured in England upon this system, and which give excellent results. We saw these samples at the office of Mr. Philip S. Justice, of 14 Southampton Buildings, Chancery Lane, London, who, we understand, represents Mr. Dupuy in this matter, and is introducing the system into England.

UNIFORM STANDARD TIME.*

By SANFORD FLEMING, M. I. C. E.

THE question which I have been requested to bring under the notice of the Convention, although not strictly of an engineering character, yet, from its nature, cannot fail to be of interest to the members of the American Society of Civil Engineers, many of whom have taken a prominent part in establishing the great lines of communication on this continent. To the large number of its members connected with the administration and development of the gigantic railway system extending between the two oceans, which in length are but little less than 100,000 miles, the subject becomes one of vital importance.

The occasion strikes me as peculiarly appropriate for submitting for your consideration the subject to which with your permission I will briefly refer. The Society meets for the first time beyond the limits of the United States, to find in the Dominion of Canada a cordial welcome. Many of its members in attending this Convention must have traveled long distances, and have experienced, in one way or another, some of the difficulties it is proposed should be removed.

The definition of civil time and its scientific determination for railway, telegraph and all ordinary purposes, is a problem to which a solution is imperatively demanded by the present condition of civilization.

The question has been examined by the American Metrological Society, New York; the Imperial Academy of Science, St. Petersburg; the Royal Society, London, England; the Canadian Institute, Toronto, and other scientific bodies.

Its importance has been fully admitted and expressions of opinion have been obtained as to the means of overcoming the difficulties which are experienced.

The citizens of the United States and the subjects of Her Majesty the Queen occupy together the greater portion of North America. The most friendly relations exist between us, for, in the main, we are substantially one people, living under different governments, with laws and customs essentially identical. On all sides we are satisfied to remain separated by our political affinities, having distinct theories and beliefs with respect to systems of government. But science, like every noble virtue, knows no national boundary. In this brief note I can recognize none. In alluding to matters which equally concern the United States and Canada, I shall refer simply to this country or to this continent.

As the continent extends across 105 degrees of longitude, and an individual at the western limit finds himself seven hours of recorded time behind another individual at the extreme eastern side at the same moment of absolute time. Much of the intervening country is but thinly settled, but railways and telegraphs traverse from ocean to ocean, and we have every gradation of difference of time between the extreme limit of seven hours.

According to the system of notation which we have inherited from past centuries, every spot of earth between the Atlantic and the Pacific is entitled to have its own local time. Should each locality stand on its dignity it may insist upon its railway and its other affairs being governed by the time derived from its own meridian. The smaller and less important localities, however, as a rule, have found it convenient to adopt the time of the nearest city. The railways have laid down special standards which vary as has been held expedient by each separate management. In the whole country there is, so far, an irregular

* A paper read at the Montreal Convention of the American Society of Engineers.

acknowledgment of more than one hundred of these artificial and arbitrary standards of time. The consequences of this system are unsatisfactory. They are felt by every traveler; and in an age and in a country when all, more, or less, travel, the aggregate inconvenience and confusion is very great; and it will be enormously multiplied as time rolls on. If the system already results in difficulties to trouble our daily life, and to lead to embarrassments which often occupy our courts of law; which, indeed, too often are the cause of loss of life, what will be the consequences in a few years, when population will be immensely increased and travel and traffic indefinitely multiplied, if no effort be made to effect a change.

The societies I have mentioned, after careful examination, have united in the opinion that a satisfactory change cannot be made too soon, and they have adopted resolutions pointing to a general uniformity and thorough accuracy in time reckoning. They believe that the course they have recommended will greatly facilitate the daily transactions of business men, greatly increase the safety of the traveling public, and immensely benefit the whole community.

It is proposed that the community unite in an effort to simplify the system now in use by reducing the number of time standards to a minimum, by substituting for an indefinite number of irregularly established and purely local standards, a few main, or, as they may be termed, continental standards, each one having a fixed and well known relation to all the others. It is proposed to have these standards established and maintained by governmental authority; to have them regulated with precision through a common central observatory, and through these standards it is proposed to keep every town, city, railway and steamboat clock throughout the land as nearly as practicable in perfect agreement.

The plan of arrangements favored by the Metrological Society, New York, and the Canadian Institute, Toronto, is to have the standards so established that they will be exactly one hour apart; that is to say, while it would be nine o'clock at one standard it would be eight o'clock at the next to the west, seven o'clock at the following, and so on, by steps of exactly one hour. There would be no difference in the minutes and smaller divisions of time. If the time be ten minutes or thirty minutes past the hour at any one point, it would at the same instant, in absolute time, be ten minutes or thirty minutes past some hour at every point. The hours themselves only would differ, and they would differ only in designation according as the localities were east or west. At the same instant of absolute time every clock in the country would strike either one hour or another, the minute and second-hands would always and everywhere be in perfect agreement.

It may be known to gentlemen present that the officers of the United States Signal Service, have evinced a deep interest in the question and in the efforts to establish uniformity, accuracy and simplicity of system throughout the country. General Hazen, Chief Signal Officer, Washington, has expressed his earnest desire to contribute toward the public dissemination of standard time. He considers it eminently proper that the department over which he presides should, as far as practicable, assist in a work in which the whole community is interested, and he offers the active co-operation of the Signal Service in every part of the United States, in the maintenance of accurate standard time, and giving it to the public by dropping time balls at all important stations.

Mr. Carpmael, Chief Director of the Meteorological Department of Canada, would similarly co-operate in every practicable way. There would, therefore, be no difficulty in giving effect to a scheme of introducing uniformity of time reckoning throughout North America, so soon as the railway and telegraph authorities and the general public express concurrence.

It is proposed—1. That the exact time should be determined astronomically at a central observatory; 2. That every town of any importance should have a public time signal station; 3. That arrangements be made for placing each station in electrical connection with the central observatory at a certain hour every day; 4. That each station be furnished with automatical apparatus for making the proper signal, either by dropping a time

ball or by firing a gun at the proper moment; 5. That all the public and railway clocks in each and every locality be controlled electrically from the public time signal station.

I think it may fairly be claimed that no peoples are more progressive or more ready to adopt any needed change or manifest improvement than those who live in North America. And as there is no country except Russia where a greater necessity is presented, or a better field offered for the introduction of a comprehensive system of uniformity in time reckoning, it is more than probable that in this country the change will first be made.

As there can be little doubt that other countries will in due time follow the example of America, it is desirable that we should inaugurate a system which will readily commend itself by its appropriateness and simplicity. One that will have the best prospect of being ultimately adopted throughout the world. If we admit the principle that in a question of this kind it is not expedient to limit our view to any City or State or Province, but to embrace in our system the whole of the continent, it seems to follow that we should take a still broader view, and endeavor to apply the principle to all countries. Steam and electricity are rapidly altering the conditions of life everywhere, they are girdling the globe and bringing all countries nearer together. We get our unit measure of time from the earth's revolutions, it is therefore common property, and nothing can be more cosmopolitan in its nature. It is perfectly obvious to my mind that a system of uniform time which would be good for this country should be equally good for all countries on the face of the globe.

These views have met with the ready acquiescence of all who have given them careful consideration, and the system recommended by the several scientific bodies, for adoption on this continent, commends itself as a scheme which all nations may, with advantage to themselves and to general interests, accept.

The American Metrological Society and the Canadian Institute have each passed resolutions substantially as follows:

Resolved, That uniformity of time throughout the United States and Canada is demanded by the progress of events, and that a general system by which time may be reckoned in a uniform and accurate manner by the people of all nations throughout the globe is of the highest importance.

Resolved, That a great service will be rendered to the world by directing the public mind to the subject, and by securing the general adoption of a well-conceived system of uniformity, and that the society is hereby authorized to coöperate with other bodies in recommending a comprehensive scheme based on the following propositions:

1. Twenty-four standard meridians (one every 15 degrees of longitude) to be established around the globe for reckoning sectional or local time.

2. One of the twenty-four standards to be selected as a time zero or initial meridian for reckoning cosmopolitan time.

3. The time zero to coincide with the prime meridian to be common to all nations for computing longitude.

4. The twenty-four standard meridians to be designated by names, or by letters of the alphabet, or by degrees of longitude, numbered from the prime meridian westerly.

5. The prime meridian or zero for time and longitude to pass near Behring's Strait, 180 degrees from Greenwich.

6. The division of the day into two halves of twelve hours each to be discouraged, and a single series numbered from I to XXIV, substituted. In the cosmopolitan day, or period of time between two successive passages of the sun over the prime meridian, the single division to be made absolute.

I may avail myself of this opportunity of mentioning that the scheme of cosmopolitan standard time is being brought before various European societies under distinguished auspices. His Excellency, the Governor General of Canada, has been good enough personally to evince a deep interest in the question, and has been pleased to send communications to France, Belgium, Prussia, Austria, Russia and Switzerland. The subject will be considered by the Association for the Reform and Codification of the Law of Nations, at their meeting in August next at Cologne, in Rhine-Prussia; and it will,

on that occasion, find warm advocates in Dr. Barnard, president of Columbia College, and Mr. David Dudley Field, of New York. The question will be brought under the consideration of the International Geographical Congress, at Venice, in September next, supported by such men as Mr. Otto Strove, director of the Imperial Observatory, St. Petersburg; General Hazen, of Washington, and others.

In bringing these propositions under the notice of the American Society of Civil Engineers, I do not feel justified, on an occasion like the present, to refer at length to the voluminous papers which have been written, and the arguments which have been advanced, in connection with this question. Necessarily I have been brief, and I respectfully suggest, in order further to save the time of the convention, that a committee be appointed to examine and report at a future meeting.

I feel it proper to add that as the great object is to determine and establish a system which will secure the greatest advantages to the community, it is of vast importance to have the proposition carefully digested by those whose opinions have value with the public. An expression from this body of educated, scientific and practical men, must carry with it great weight, and will exact respect in every quarter.

In the discussion upon Mr. Fleming's paper, Prof. Hilgard, of Washington, expressed himself as coinciding with the author, and further said:

"It was proposed to have twenty-four meridians at different places in the world, which would be just one hour apart. At every one of these meridians the time will be the true time of the place; half an hour east of it the time will be slow, and half an hour west of it the time would be fast. There would be some difficulty about the time between the meridians, but the system would possess undoubted advantages over the present complicated one. If the system were adopted on this continent, and other continents followed suit in adopting it, they would then have the first meridian, from which all other times would be regulated on this continent."

THE PROJECTED SIMPLON TUNNEL THROUGH THE ALPS.

By G. T. LOMMEL.

Abstracts of Institution of Civil Engineers.

In an elaborate paper presented to a recent meeting of the Swiss scientific Society at Brigue, the author, as engineer and director of the Simplon Company, propounds his views on the internal temperature likely to be encountered in driving the projected tunnel through the Simplon, and on the plans consequently to be recommended for carrying out this great work.

Temperature.—After noticing various earlier data with regard to the internal temperature of the earth's crust, the author turns to the temperature observations obtained in the Mont Cenis and St. Gothard tunnels, plotting them graphically in the latter instance in connection with the mountain profile along the line of the tunnel. The general principles bearing upon the outward emanation of heat from the earth's interior, and the inward penetration of cold from its surface, are noticed in relation to mountainous country; but it is thought premature to attempt the construction of any general formulæ, for which far more numerous observations are yet needed. The conclusions deduced by Dr. Stapff* from the St. Gothard tunnel, and applied by him to the Simplon, are warmly combated at considerable length. Longitudinal sections showing the similarity of the mountain profiles along the line of the tunnels are given by the author for St. Gothard and Mont Cenis; and from a comparison of these he infers that, for the middle of the St. Gothard tunnel at 5,600 feet depth below the mountain summit, the maximum temperature of rock in the advance heading,

* *Vide* Minutes of Proceedings Inst. C.E., vol. lxii., pp. 399–407.

which was found actually to be 30.8° C. or 86½° F., might have been conjectured nearly enough, without the aid of any formulæ, from the 29½° C. or 85° F. previously observed in the middle of the Mont Cenis tunnel for its depth of 5,300 feet below summit. Even supposing Dr. Stapff's inference were admitted, of 47° C. or 117° F. for the rock temperature at the middle of the Simplon tunnel, the author is satisfied that by abundant ventilation the air temperature at the working places might be maintained some 10° C. or 18 F. lower; inasmuch as in the Comstock* mines, Nevada, with a rock temperature of 130° F. or 54½° C., the air temperature in the workings is by that means kept down to an average of between 108° and 116° F. or 42° and 46½° C. High temperature he regards as of secondary moment, the freshness of the air being the most important consideration.

Route.—For tunneling through the Simplon at its base, the author gives a plan showing three alternative routes of his own, for tunnels of about 11½, 12¼, and 12⅓ miles length; also a tunnel of about 12½ miles proposed by Herr Stockalper, with another of nearly 13½ miles. Of his own three proposals, the shortest tunnel has its northern end within half a mile of Brigue, in the hillside near the mouth of the Saltine ravine; while the other two start within 2 miles further northeast, from the Rhone valley a little above Brigue. The southern ends of all three are about ½ mile from Iselle, in the valley of the river Diveria. The longer routes starting from the Rhone valley involve heavier outlay on the tunnels themselves, but lighter on the approaches to them; their summit level is also from 60 to 160 feet lower, thereby easing slightly the gradient on the southern approaches; moreover, the conditions affecting temperature are in their favor. With all the experience gained at Mont Cenis and St. Gothard, the author considers the Simplon tunnel will be executed under much better conditions, its northern mouth being near the railway terminus at Brigue, while up to its southern mouth temporary rails can be laid with locomotive gradients along the 11¼ miles of road from the railway terminus at Domo d'Ossola. The valleys at each end of the tunnel are easy of access, and are inhabited; and their climate is that of the plains. Very extensive air-compressing and ventilating machinery should be provided, of at least 2,000 HP. at each mouth; for this purpose ample water power is available at the northern end from the Rhone, and at the southern from the Diveria with its tributary the Cherasca.

Mode of Driving.—The author agrees in recommending the English method, adopted at Mont Cenis, of driving the advance heading along the floor level of the completed tunnel; in preference to the Belgian method, adopted at St. Gothard, of driving the heading along the roof of the tunnel. In the latter case the driving of the heading was followed by its enlargement to the full size of the arch forming the upper half of the tunnel; then along one side of the lower half a trench, called the *cunette du strosse*, was excavated down to the final floor level; and lastly the *strosse** itself, or ledge remaining along the other side, was got out. The serious practical disadvantages attending the roof heading are dwelt upon in detail; the floor level of the portion excavated is incessantly changing, as the successive stages of the work are pushed forwards, causing continual delays for shifting the rails, pipes, and culverts; the successive enlaregments in rear of the heading cannot be got out rapidly, or at any rate not economically; and as these enlargements have to be made below the level of the heading, it is almost impossible to multiply the number of the working places. On the contrary, as the author illustrates by comparative diagrams, the other method, with the advance heading driven centrally along the bottom of the tunnel, presents the advantages not only of more favorable conditions in regard both to temperature and to health, but also of facilitating the ready removal of the spoil; in very long tunnels the latter consideration, taken in connection with speed of driving, outweighs all others. The rails &c. originally laid are here kept in use throughout to the completion of the tunnel, without ever having to be

* The figures here given are quoted from Professor Church's paper in the Transactions of the American Institute of Mining Engineers, vol. vii., pp. 46–9. *Vide* also Minutes of Proceedings Inst. C.E., vol. lvii., pp. 393–6.

* This is simply the German word *strosse*, a step, bank, or ledge.

shifted; the excavation of the subsequent enlargement is above the level of the heading; and consequently any number of working places can be opened out, and kept going simultaneously, without impeding the continuous removal of the spoil.

For the Simplon tunnel the author accordingly recommends concentrating operations, during the first years of the work, upon driving the heading along the bottom of the tunnel from each end, and deferring its enlargement almost wholly until the two headings meet. As they advance, however, a preliminary enlargement to the full size of the finished tunnel should be opened out at about every 1,100 yards distance, for a length of 90 to 110 yards, which should be completed with its lining of masonry. Each of these enlargements would be executed during the time of driving the heading through the next stage of 1,100 yards; and thus there would never be more than a single working place in operation in rear of the heading forebreast. Hence, the inconveniences and delays involved in keeping a number of working places going during the driving of the heading would be done away with. The permanent culvert excavated below the floor of the heading would be pushed forwards at the same rate, keeping it always up to within 100 yards in rear of the forebreast. The preliminary enlargements successively completed would afford conveniences for shunting and for storing materials; and as soon as ever the two headings meet, each of these places would present two working faces for pushing on the final enlargement of the rest of the tunnel with the utmost convenience and despatch. On this plan, the haulage could be done throughout by compressed-air locomotives, running at 9 to 11 miles an hour in the tunnel, and aiding the ventilation by the fresh air they discharge; and horses, which, besides their power being so expensive, vitiate the air worse than four times as many mén, and keep the roadway always trodden up and foul, are done away with altogether. The work of drilling the blasting holes should, in the author's opinion, be done entirely by mechanical means, avoiding any use of manual labor for this purpose.

Allowing six to seven years for the completion of the heading throughout its entire length, with a sectional area of about 100 square feet, the further excavation of the tunnel to its full section of about 380 square feet (exclusive of the heading) would then be pushed forwards simultaneously in each of the fifteen to twenty preliminary enlargements along the course of the heading. In every one of these places would be erected a pair of huge traveling stages, for which a design is sketched; each staging would serve alternately for miners and for masons, so that, after driving one face for some 30 yards length, the masonry lining would be built up along that length, while the drills were shifted to drive the other face. With thirty drills, 100 to 120 holes could be bored to a depth of $4\frac{1}{4}$ feet in the working face, in four shifts of half an hour each; and allowing four hours more for blasting and clearing, six hours would suffice for $4\frac{1}{4}$ feet in advance. Halving this rate, to be safely within the mark, there would be two blastings per twenty-four hours, giving an advance of $8\frac{1}{2}$ feet. Hence with about 1,000 yards length to be excavated between each of the preliminary enlargements, the whole length of the tunnel would be completed to its full section within a year (seven days per week) after the heading had been driven through, or say fifteen to eighteen months at the outside. For removing the collective spoil of 1,500 to 2,000 cubic yards of rock per day from the whole tunnel, the author estimates that a stock of fifteen locomotives and two hundred roomy wagons would be ample, allowing one-third to be idle.

The paper is supplemented by a somewhat detailed sketch of the general arrangements proposed for driving the heading; for excavating the preliminary enlargements: for completing the entire tunnel to its full section; and for conveying the workmen, materials and spoil.

In a letter on the heat in the tropics, to the editor of the *Times*, Mr. G. J. Symons gives the following as the highest point reached by the shade thermometer in the years 1874–80:

	Barbados. deg.	Mauritius. deg.	London. deg.	Bombay. deg.
Average for 7 years....	84.9	87.3	87.4	93.9
Absolute highest....	86.0	88.8	92.6	96.3

THE GOLDSCHMID ANEROID.

A FORM of barometer made in Zurich, and known as the Goldschmid Aneroid, has of late been extensively employed in this country in railway reconnoisance, as well as in more extended topographical work.

The simplicity of its mechanism seems to promise some advantage over the forms heretofore in use.

One of the oldest forms of *box* barometer and the one to which the name *aneroid* is restricted by some writers, is represented in Fig. 1. A rectangular

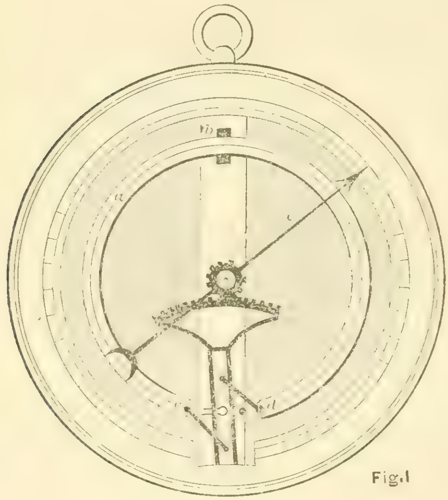


Fig. 1

tube, from which the air has been perfectly exhausted, is sealed hermetically, and having been bent into the form represented in the figure by *cbd*, is made fast at the middle point *b*. The varying pressure of the atmosphere causes the extremities *c* and *d* to approach or recede from each other. This motion is converted into a to-and-fro traverse of the index, by a mechanism sufficiently well exhibited by the diagram.

The form chiefly used at the present day, and sometimes designated as the Holosteric Barometer, is represented in Figs. 2 and 3. The vacuum box is in this case a short cylinder *h*, having an elastic top corrugated in concentric rings. A thin steel spring is made fast to the outer case at *l*, and, bending over, is attached to the vacuum box at its center.

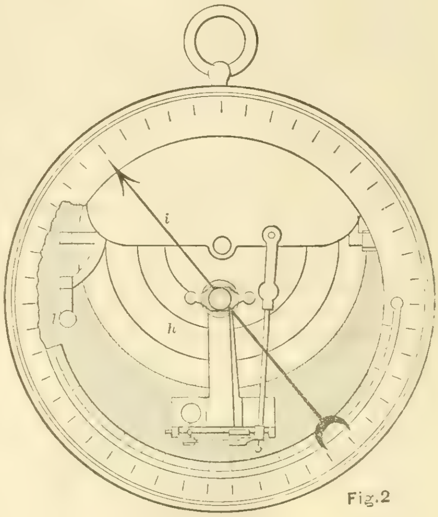


Fig. 2

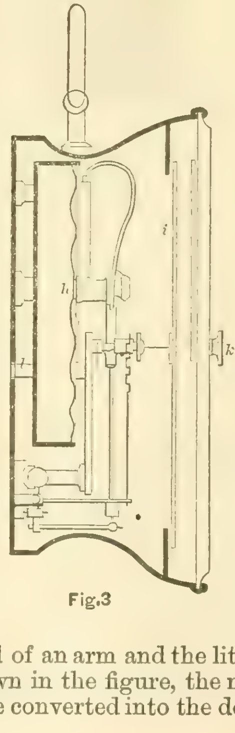


Fig. 3

By the aid of an arm and the little rocker-shaft shown in the figure, the motions of the box are converted into the desired mo-

tions of the index, by means of a minute chain which winds about the center pin which carries the pointer. This chain is shown by a wavy line in both figures. A small hairspring supplies a slight counter pressure.

The graduation of these instruments is made to correspond with the height of the mercurial barometer, and is expressed as inches or millimeters.

The difficulties to be met by the maker, in securing accuracy of working, are those which arise chiefly from the varying elasticity of the several metallic elements under change of temperature. Greater simplicity of construction might be presumed to be attended with a smaller liability to a kind of error, for which it is exceedingly difficult to compensate. This is the theory of the Goldschmid Aneroid.

The instrument designed for ordinary engineering use is represented by Fig. 4. The size recommended by the present makers for this service is $3\frac{1}{8}$ inches in diameter and $2\frac{1}{2}$ inches high.

Fig. 4

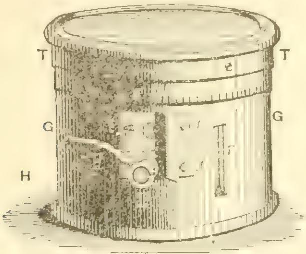


Fig. 5

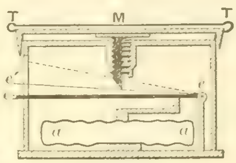
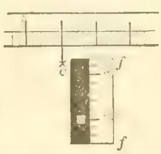


Fig. 6



The construction is exhibited by Fig. 5. The vacuum box, constructed as before described, is shown at *aa*. The motions of the box, caused by variations of atmospheric pressure, are conveyed directly to the lever, whose fulcrum is at e'', and whose free end is at e. This end, projecting through the side of the casing and working freely through a slot, is observed with a magnifying lens, and the reading on the index *ff* taken. But it is evident that the lever, working with proper ease on its fulcrum, must be supplied with a certain amount of counterpressure. This is ingeniously done by aid of the delicate spring e', which is attached to the lever near the fulcrum. Bearing on the spring is the point of the micrometer screw M, whose head is graduated to hundredths and forms the top of the case. Both lever and spring are furnished at their extremities with bright metal heads, whose end surfaces lie in the same plane. The head e' is, under ordinary conditions, higher than e, as shown in Fig. 5. When a reading is to be taken the top of the case is turned until e' and e are side by side; the horizontal marks borne on the metallic heads being brought to an exact coincidence by aid of a lens (P in Fig. 1). The reading of the *inches* is taken from the scale *ff*, and of the hundredths from the divisions on the scale around the top of the box T; a fixed point c being marked on the cylinder. In figure 6 the indices exhibit a reading of 29.75 inches.

The thermometer F is an important part of the instrument.

In some of these instruments the scale *ff* bears no reference to the inches of the mercurial barometer, but is of an arbitrary character, and is different for different instruments. The value of the divisions is determined by comparison with standard instruments, and is carefully expressed in tabular form on the cover of the box.

Some corrections for temperature and pressure are required in the use of these instruments which, although desirable in the more common forms of aneroid, have not heretofore been considered necessary. In the latter instruments, however, when of the best construction, a *compensation* has been effected which renders a correction for temperature unnecessary. In the Goldschmid aneroids no compensation is attempted, but each instrument is furnished with a table of corrections which have been prepared from observation on standard instruments.

Thus, aneroid No. 3187, imported

last year, bears on the cover the following:

CORRECTION TABLE.

For Division.	*For Temperature.*
26.0″ = −0.02	28° to 48° = 0
26.5″ = −0.03	52° = +0.01
27.0″ = −0.03	56° = +0.015
27.5 = −0.02	60° = +0.025
28.0 = 0	64° = +0.035
28.5 = +0.03	68° = +0.04
29.0 = +0.06	72° = +0.05
29.5 = +0.10	76 = +0.07
30.0 = +0.14	80 = +0.09
30.5 = +0.19	84 = +0.11
31.0 = +0.25	88 = +0.13
	92° = +0.15

The temperatures are, of course, taken from the thermometer that forms a part of the instrument, and which, when the latter is carried slung from the sholder, may exhibit a temperature considerably higher than that of the air.

Two examples of altitudes taken with the instrument previously referred to (No. 3187) will serve to show the kind of correction necessary, and as both examples apply to the same mountain (Kiarsarge of Conway, N. H.,) they will together indicate the character of the instrument.

Ex. I.—July 9th, 1881.

Station.	Time.	Bar. Reading.	Temp. Air.	Temp. Inst.	Correct'ns Temp.	Correct'ns Press.	Corrected Reading.
Fryeb'g.	6.00 A.M.	29.51	66°	66°	+.04	=.10	29.65
Mt. Kiarsarge..	1.00 P.M.	26.75	74	74°	+.06	−.03	26.78

Ex. II.—August 9th, 1881.

Station.	Time.	Bar. Reading.	Temp. Air.	Temp. Inst.	Correct'ns Temp.	Correct'ns Press.	Corrected Readings.
Fryeb'g.	7.00 A.M.	29.34	60°	65°	+.03	+.09	29.46
Mt. Kiarsarge.	1.20 P.M.	26.48	65°	75°	+.06	−.03	26.51

In both these examples another reading would have been taken at Fryeburg on the return, if the better alternative of securing hourly readings of a stationary barometer at Fryeburg had not been followed. On July 9th there was no change in the Fryeburg barometer. On August 9th the following readings were taken at Fryeburg:

7 A. M.	29.53	1 P. M.	29.46
8 "	29.52	2 "	29.455
10 "	29.515	3 "	29.40
12 "	29.46		

As this set of observations indicates a fall of .07 in the interval between the base and summit readings, it becomes necessary to make another correction to the last column.

Correcting the first reading to accord with the fall indicated by the stationary barometer, we get after all corrections:

Fryeburg, 29.39.
Mt. Kiarsarge, 26.51.

A convenient formula for estimating heights from barometric observations is

$$D=60000\,(\log. B-\log. b)\left(1+\frac{T+t-60}{900}\right)$$

in which

D = difference in altitude in feet.
B = height of barometer in inches at lower station.
b = height of barometer in inches at upper station.

T and t are the temperatures of the air in Fahrenheit degrees.

Applying this formula to our first example we have:

$$D=60000(1.47202-1.42781)\left(1+\frac{140-60}{900}\right)=2887 \text{ ft.}$$

The second example gives:

$$D=60000(1.46820-1.42341)\left(1+\frac{125-60}{900}\right)=2881 \text{ ft.}$$

As the station at Freyburg is 434 feet above the sea, the estimated total height of Kiarsarge would be, in one case, 3321 feet, and in the other 3315 feet.

Prof. Airy's table gives 3319 and 3314 from the same data.

The instrument employed in the above measurements has been used in many other cases of altitudes from 3000 to 4000 feet. An error of about 2 per cent. in excess has been detected in those cases where the altitude has been measured by more accurate means. It seems likely that the special correction table needs some slight revision.

There is no doubt that all aneroids

need a careful comparison with standard instruments or a series of trials upon known altitudes, in order to determine the proper corrections. Such trials should be made at different temperatures and under different conditions as to rising or falling at the time of observation. The tables of corrections furnished by the maker cannot well be substituted for those made by a careful observer deduced from systematic work. The air pump, the hot chamber and the freezing box are convenient, but inadequate substitutes for a large number of trials under normal conditions.

Fig. 7

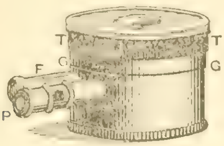
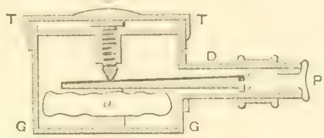


Fig. 8



With an aneroid, whose working is familiar to the engineer, there seems to be no reason why it should not be substituted for the level in all preliminary surveys. The field notes required would be the same as in the foregoing example with the *distances* in the place of the names there given. The calculations would be much simpler than is indicated by the formula applied in these cases.

For contiguous stations the following table from Symons' Pocket Altitude Tables may be conveniently employed:

Mean temperature...	30°	40°	50°	60°	70°	80°
Mean presssure, 27in.	9.7	9.9	10.1	10.3	10.6	10.8
" " 28in.	9.3	9.5	9.8	10.0	10.2	10.4
" " 29in.	9.0	9.2	9.4	9.6	9.8	10.0
" " 30in.	8.7	8.9	9.1	9.3	9.5	9.7

To find the difference in height between two stations: Find the mean pressure; also the mean temperature. The number in the table corresponding to these two means, if multiplied by the difference of the barometric pressures in hundredths of an inch, will give the difference in altitude very nearly.

The Goldschmid aneroid recommends itself by its construction, and although the errors are more numerous and larger than in the better class of *compensated* instruments of the *holosteric* pattern, it is reasonable to presume that they may be measured with greater certainty, and therefore more completely corrected.

A smaller and ruder instrument called the Pocket Aneroid is made by the Zurich manufacturers. It is only $1\frac{1}{2}$ inches in diameter and $1\frac{1}{4}$ inches high. A bar fastened to the top of the vacuum box takes the place of the lever in the larger instrument.

A larger size is also made in which the movements of the vacuum box are directly observed with a compound microscope.

Writing in answer to a question on cleaning out lime-incrusted water pipes, a correspondent of the *American Manufacturer* writes: "As a sort of 'shop kink' I give you a curious experiment tried on an engine water supply pipe that had become choked up with lime incrustation. After hammering it for an hour or two and kindling a fire all over it, without any result, one end was plugged up, and about a pint of refined coal oil was poured in the other end—all it would hold—leaving it to stand all night. The next morning the entire mass slid out a solid lime core."

A variety of coal, said to be the most highly-carbonized member of the coal series hitherto described, has been found near Schunga, on the western shores of Lake Onega. It contains about 91 per cent. carbon, 7 or 8 per cent. water, and 1 per cent. ash. This coal is extremely hard and dense, has an adamantine lustre, is a good conductor of electricity, and has a high specific heat—0.1922. Although containing as much carbon as the best graphites from Ceylon, it is not a true graphite, inasmuch as it is not oxidized by potassium chlorate and nitric acid, but behaves towards those re-agents like an amorphous coal.

THE ART OF FOUNDING IN BRASS, COPPER, AND BRONZE.*

By EDWARD TUCK.

From "The Architect."

The origin of the art of founding can only be a matter of speculation, extending as it does so far back in the past history of the race, a history to a very large extent wrapped in obscurity and mystery. But the marvelous results of the various operations and the immense importance they have to mankind, have caused many in ancient times to assert that the art was communicated to man by the gods. Some, and with a larger share of truth, consider that man, finding by accident that certain minerals by the force of fire yielded a metal, repeated the experiment on other minerals, finding out other metals, and thus ultimately all the differing forms in which they exist in the earth. As late as 1762 a large mass of mixed metals, composed of copper, iron, tin, silver, was melted out of the earth during the conflagration of a wood accidentally set on fire, and various ancient historians speak of metals having been melted out of the earth during the burning of woods in the Alps and Pyrenees.

Copper is occasionally found in nature in a metallic state so pure as to be used for manufacturing purposes either for making articles of copper or alloys. There are examples of this in the mines of Lake Superior in North America, where large masses of copper have been found weighing several tons. It may, therefore, be considered quite possible that quantities of copper were found in the earth in the olden time, so that the ancients could possess the metal without the necessity of smelting. But, however, this fact must be stated, that where a mass of copper is found embedded in the earth at any depth it would require a greater amount of skill and mechanical knowledge to get this into working operations than to smelt the ore. Such a mass could not be broken up like stone, but must be cut, and therefore would require tools of particular hardness, and other mechanical appliances, to obtain which requires a greater and more refined knowledge of metallurgy than smelting copper from the ore.

But whatever or wherever may have been the origin of the art, it is quite certain that it originated at the very earliest period of man's history and has gone down with him along the stream of time to this age. It has had, as all arts have had in varying ages and nations, its rise and decline, which make the investigation of its history a somewhat difficult task. Still, by the aid of researches which have been made amongst the ruins and relics of past buried ages, we have been able to gather together some facts which help us to form something like a history of the art, very imperfect in many points, yet enabling us to form some idea of the methods of working and the means by which certain results which are matters of wonder to us even now were accomplished.

We have, it is true, in these modern days advanced far, very far, in the metallic arts; but in the great facts and principles we are no farther than the men of the past. In the matter of tools and means of production we have advanced so that we may produce in one week as much as they did in one year. But still the fact remains, *they accomplished the work*, and in the especial matter of bronze we have not yet reached the height of perfection to which certainly they attained.

Pliny and other ancient writers are very far from being correct in their descriptions of the manufacturing processes; and even the translators of their works have added to the confusion, either through ignorance, or on account of the poverty of the original language in technicalities, as we find brass in one place, white copper in another, copper in a third, all referred to indiscriminately, whether referring to pure copper or the

* A summary of the second prize essay of the Worshipful Company of Founders, 1880–81.

alloys whitened by the addition of lead, tin, or any other process; although Pliny certainly does describe more correctly the casting of bronze, for he says: "The mass of copper was brought to a liquid state, then was thrown into a third part of old bronze and 12½ per cent. of plumbum argentarum," *i.e.*, tin and lead in equal parts. We shall, therefore, trace the history of the art of founding, so far as we have been able to gather it from the past history of ancient times and the researches into and about the buried cities, and trace its course down through the ages to the present time.

The oldest reference we find in Holy Writ is in the Book of Job (the oldest work extant), Ch. xxviii. 2, "Brass is molten out of the stone." In the original Hebrew the word is *Nechosheth*, meaning literally copper. This must be so, as brass, being an alloy and not a pure metal, is not smelted, or, as it is put here, "molten out of the rock." The next reference is in Genesis iv. 22; "Tubal Cain, an instructor of every artificer in brass and iron." The same word, *Nechosheth*, is used here, literally copper; but seeing that copper is a difficult metal to work, we believe that the alloy of copper bronze is really meant. We incline to this belief because there is only one other reference to copper in the Old Testament (Ezra viii. 27): "Two vessels of fine copper, precious as gold." And here the same word is used. We find that tin, which mixed with copper forms bronze, certainly was known to the ancient Israelites, as in connection with the spoil taken from the people of Midian 1452 B.C. (Num. xxxi. 22) they are commanded by Moses to purify the silver, brass, iron, tin, and lead by passing it through the fire. (Moses appears here to mention all the metals then known.) Whether the tin came from India or not there is no sufficient evidence to prove, but it appears certain that the productions of that land were known in the earliest times, by "the gold of Ophir" being mentioned in Job.

If the Phœnician ships did not actually sail to India, its productions arrived partly by land through Arabia, partly through more distant marts established midway from India by the merchants of those and later times; and we have evidence of their having arrived in Egypt at the early period of Joseph's having been taken there, by the spices which the Ishmaelite caravans were carrying to that land. And the amethyst and other objects discovered at Thebes, of the time of the third Thothmes and succeeding Pharaohs, and which must have been brought to Egypt, argue very strongly that the intercourse was constantly kept up. Bronze, composed of tin and copper, was found in Egypt of the time of the sixth dynasty, 2,000 years B.C.

The first work of art of which we have any details in Holy Writ is the Ark made by Moses, and generally called "the Ark of the Covenant." It was also the first work performed by the Israelites as a nation. A large portion of the works in connection with this are of pure gold beaten out with the hammer; and although these show mechanical skill of a very high order, they are outside the scope of our paper.

We read (Exodus xxxviii. 8), "And he (Moses) made the laver of brass, and the foot of it of brass, of the looking-glasses of the women," &c. The word translated "foot" should be, as given in the margin, "cover." This laver, or large basin, in which the priests were to wash, must have been a large work to cast; and it shows a complete and accurate knowledge of the different sorts of bronze for different purposes that the cover should be made of the mirrors of the women, brought by them out of Egypt, and which, containing about one-third more of tin in the alloy, constituted speculum metal. So that the cover of this huge washing basin formed, when raised, a mirror in which the priests could examine themselves before approaching the altar. There were besides this many other articles used in the erection of "the Ark of the Covenant" made of bronze. Dean Prideau gives as the weight of bronze used 10,277 lbs. troy weight. The entire weight of the articles made in the three metals, gold, silver, and brass or bronze, was 14 tons 2 cwt. No one can read over the narrative of that undertaking, viewed independently of the adverse circumstances of the Israelites, wanderers in the wilderness, without perceiving that many amongst them possessed great skill; some had most probably been amongst the highest class artisans of Egypt. The ease with which

these elaborate works connected with the Ark, as well as the Golden Calf and the Brazen or Bronze Serpent, were produced, show that they had not been employed solely in the labor of brickmaking whilst in Egypt, but that in all probability many of them were working men in the Egyptian foundries and other public works in which metal articles were manufactured.

Bronze being a mixture of copper and tin in variable proportions, every variation produces a bronze of different quality, more or less suitable for different purposes. One quality will have great hardness and be very brittle—another hard and flexible; one gives a bright reflecting surface when polished, suitable for mirrors—another is famous for its sonorous quality, and is therefore suitable for bells, gongs, &c. Before these properties and differing qualities could have been found out some length of time must have intervened, as such knowledge of practical facts could not have been obtained until society had gained a considerable advancement in the arts. We are able to show by analysis that have been made of the bronze of the Egyptians and other ancient nations, that it was of such varied qualities, requiring a great amount of knowledge and practical skill as well as pure materials. Consequently these ancient people must have attained the knowledge before they could procure the varied articles. A chisel found by Wilkinson in an Egyptian quarry gave copper 94.0, tin 5.9, iron 1=100. A dagger, analyzed by Klaporth, copper 91.6, tin 7.5, lead 0.9=100. Bowl or dish from Nimroud, copper 89.57, tin 10.43=100. Bell analyzed by Dr. Percy, 84.70, tin 14.10. Thus showing where sound is required the amount of tin is increased, where strength is required the amount of tin is decreased. Dr. Percy found also a small casting, in the shape of the foreleg of a bull, forming the foot of a stand consisting of a ring of iron standing upon 3 feet of bronze. A section made disclosed a central piece of iron over which the bronze had been cast. The casting was sound and the contact perfect between the iron and the surrounding bronze, and it was quite evident on thorough inspection the bronze had been cast round the iron, and not the iron let into the bronze. The analysis gave copper 88.37, tin 11.33. No perfectly satisfactory conclusion can be arrived at whether the iron was employed because required in the construction or to economize the more costly metal—the bronze required for the ornamental purpose; we are inclined to the former in this case. Sir Henry Layard speaks of the bronze vessels, which he supposes to have been used in the religious ceremonies, as especially deserving of attention, as demonstrating the skill of the Assyrians in their treatment of bronze. One specimen may be particularly noted: "A thin hollow casting in bronze which was attached to the end of one of the arms of the throne. This casting had evidently been chased, and for that purpose must have been filled with some substance, such as pitch, which is used at the present time, as in the interior was some black compound which was like pitch and left an earthly residuum, and was probably a mixture of asphaltum and earth." It is quite evident that the Egyptians at the time the children of Israel were in captivity amongst them, and even long before that period, were very skillful in working the metals, especially bronze. We have no exact idea of the form of the furnaces or the materials used in their construction, but that they had great facility in constructing such furnaces is evident from the short time taken by Aaron to cast the calf or bull when in the wilderness. So we may presume that the Hebrews had been many of them laborers with the skilled artificers of Egypt, and, when leaving, had taken away their tools and the knowledge of the art in which they had worked with them. But whether the same or similar means were adopted for overcoming the difficulties of founding as in the present day, this fact remains, the difficulties were overcome, and the metals then known were used in abundance and as pure as we now have them. Wilkinson, in "Ancient Egypt," gives the figure of a smelting or melting operation from one of the ancient monuments. The furnace seems only a heap of fire on the surface of the earth, and the bellows are two large bags filled with air, upon which a man is standing with a foot on each bag, the aperture of the bag being connected with a pipe leading into the fire. While the man appears to be putting all his

weight on one bag to compress the air out into the fire, he is lifting up his other foot, and at the same time the upper fold of the other bag by a string in his hand, by which the bag is again being filled with air. This apparatus is no doubt both simple and rude, and if it refers to the ordinary metallurgical operations performed by the nation, one could hardly suppose that castings of any great size could be obtained except with much difficulty. Still it shows that the methods adopted for getting an intense heat were similar to ours, viz., by bellows or blowing.

Ordinary bellows are said to have been invented by Anacharsis the Scythian, but that must have been long subsequent to this period. Very little can be discovered to illustrate the means employed in metallurgical operations from the objects found in the excavated tombs, or from the paintings beyond the use of the blowpipe and the forceps, and the concentration of heat by raising cheeks of metal round three sides of the fire in which the crucibles were placed. Homer notices "that the Egyptians and other Asian workmen excel in the manufacture of arms, rich vases, and other objects inlaid and ornamented with metal." Herodotus and Helanius both say, "the Egyptians drank out of bronze goblets." We find that statues, musical instruments, implements of all kinds, adzes, axes and chisels, articles of funiture, bedsteads and footstools, and many other domestic utensils were all made of bronze. Also biers, on which the bodies were placed after death. The Egyptian vases are numerous and to be noticed for beauty of form and the design ornamenting them, as well as for the superior quality of the material. Those used in the service of the temples were especially beautiful. One found by Mr. Salt had an elastic spring to the cover, and the nicety with which it is fitted exhibits evidence of great skill in the workmanship.

The sistrum was, *par excellence*, the sacred musical instrument, and was usually of bronze or brass, sometimes inlaid with silver. One now in the British Museum is entirely of bronze, having a hollow handle closed by a movable cover of the same metal. The cymbals, or clappers, which when struck together emitted a sharp metallic sound, were of mixed metal, probably copper and silver, and in shape much resembling those of modern times.

It is not known at what times the ancient Egyptians began to cast statues and other objects in bronze, or how long the use of beaten copper preceded the art of casting. Many bronzes, however, have been found of a very early period. A cylinder with the name of Papi, of the sixth dynasty, has every appearance of being cast, and other bronze implements of the same age bear still stronger evidence of having come from a mould, all of which date more than 2,000 years before our era. The Egyptions, too, appear to have possessed the secret of giving to their cast bronze blades a certain degree of elasticity, as in the dagger now in the Berlin Museum, which probably depends for this property on the just proportions of the peculiar alloys used in its manufacture, as well as on its mode of having been hammered. Another remarkable feature in this bronze is the resistance it has offered to the effect of the atmosphere, continuing smooth and bright though buried for ages, and since exposed to the damp of the European climate. It may be said that the Egyptians had not any mines of tin wherewith to produce the bronze alloy. It is true that the mountainous districts of Egypt, between the Nile and the Red Sea, produced iron and copper only. Copper was also found in Arabia Petræa, which district was known to them, and even now amongst the heaps of refuse there we come upon the tubes used in the smelting apparatus. Mines are mentioned by Agartharchidas, a Greek writer of the age of Ptolemy Philometer, and he gives a curious picture of the mode of working these mines, which were probably near the coast now called Jebeel Allaka. For additional evidence we learn from Mak-rizi, an Arab writer, that this region produced silver and copper; and tradition names both Egyptian Pharaohs and Greek Ptolemies as workers of the mines. But, as we have already shown, they traded with India, and at this time, as well as from Spain, tin could be procured there.

The Phœnicians, to whom the art of navigation is so much indebted, and who carried the spirit of adventure beyond all the ancient nations, obtained tin from

both India and Spain long before they visited the more distant shores of Britain, and discovered how rich were the mines of that metal there. It was worth their while to undertake a long and risky journey at sea, with possibly no other method of ascertaining their course than the stars, from the high price they were able to obtain for this commodity in Egypt and other countries where, as at Sidon, the different branches of metallurgy were carried on to great perfection. Strabo, Diodorus, Pliny, and other writers mention certain islands discovered by the Phœnicians, which, from the quantity of tin they produced, they called Cassoterides, though the locality is not given, for Strabo says, "The secret of the discovery was carefully concealed;" and it is said that a Phœnician trader ran his vessel on a shoal and was shipwrecked, when pursued, rather than disclose his country's secret; for which he was rewarded from the public treasury. Strabo and Pliny both mention that tin was found in Gallicia and Lusitania, and further say that in consequence these countries became a rich mine of wealth to the Phœnicians.

Herodotus describes the doors of the Temple of Belus, at Babylon, as made of metal, probably bronze. The people would be more induced to attempt such work as bronze doors of their temples and public buildings in consequence of the scarcity of good timber suitable for the purpose in the land.

The next great work of ancient times, of which we have any details, is the making of the various bronze and brass articles used in the building and fittings of Solomon's Temple, at Jerusalem, 1011 B.C., and this gives a really good and complete idea of the progress made in the art at that period of time.

After the formation of the Ark and its various fittings, the Hebrews were not called upon again publicly to exercise their skill in metal work. The forty years of desert wanderings rendered such quite unnecessary; and as all those that came up out of Egypt died in the wilderness, in all probability with their death passed away much, if not all, the skill and ingenuity then shown, except for weapons of war and possibly implements of agriculture. They (the Hebrews) for some centuries were so much engaged in taking possession of the land they were to inhabit in wars and fightings, that the ordinary arts of civilized life were not and could not be cultivated; so that, notwithstanding the enormous wealth they had accumulated in the time of King David, yet when Solomon, his son, began to erect the Temple (which was a work their forefathers, when they left Egypt, could have accomplished without assistance) there were none among the people who could do the skilled work neccessary in casting and working the various metals. In consequence, Solomon has to negotiate with the King of Tyre to send him men and materials to do the work. "Send me, therefore, a man cunning to work in gold, in brass, and in iron," "and that can skill to grave with the cunning men with me whom David my father did provide" (referring to some skilled workmen whom the same king had sent to King David at an earlier period).

Singularly enough, the man sent by the King of Tyre as chief of the workmen was himself of Jewish descent on his mother's side, and had come of a family of metal workers, for we read, "his father was a man of Tyre, a worker in brass." This man directed the whole of this department of the work. The vastness of the quantity of bronze or brass used we are unable to determine, for we find (1 Kings vii. 47) "Solomon left all the vessels unweighed, for they were so many, neither was the weight of brass found out."

It is impossible for any one to read the graphic account given of the Temple construction in the Book of Kings, especially of the productions in metal, and not be amazed at the great variety of the work done, and the beauty and finish with which it must have been executed, as well as the great quantities and immense castings, which would require the highest mechanical skill and knowledge.

The two bronze pillars which were fixed up in the porch of the Temple must have been splendid specimens of workmanship. Taking the cubit at the generally-recognized measurement, 21 inches, the pillars, inclusive of the capitals, will have measured over 40 feet in height and 7 feet in diameter, and the weight of the metal would be from 23

tons to 28 tons. Another question arises in connection with these pillars: if they were hollow, as Whiston in his translation of "Josephus" considers they were, it follows that the use of cores must have been known and practised at this time, although this invention is ascribed to Theodorus and Rhæcus of Samos at a much latter period; but this may be only another instance of the knowledge of certain kinds of manufacture being lost and rediscovered at some later period.

In addition to these pillars, there was the Brazen or Bronze Altar, another gigantic work probably weighing about 200 tons; also the Molten Sea, an immense semicircular vessel measuring $17\frac{1}{2}$ feet in diameter and $8\frac{3}{4}$ feet deep, and containing 16,000 to 20,000 gallons of water, supported on a pedestal of twelve bronze oxen. We get no idea from the account of the size of these castings, but they must have been of sufficient size and strength to support the vessel, which, when filled with water, would weigh probably 100 tons.

In addition to these large articles, there were a large number of smaller ones, equally good in construction and workmanship; but a full description of these must be left to a further article. It is apparent that different qualities of bronze were used, for some of the articles are stated "to be of bright brass," evidently different mixtures of the alloy for the differing purposes. It is clear from the vast size of the castings that good mechanical contrivances must have been used to remove, fit up, and place them in position.

These works were cast "in the Plain of Jordan in the clay ground," or, as should be more correctly rendered, "in the depth of the clay ground between Succoth and Zarthan," showing them to have been moulded in clay. Such large quantities of metal would require to be melted in a series of furnaces, in which the metal could be fused at one time, all tapped together, and the metal let run into the mould. A series of such furnaces would be constructed in a sort of a circle or square, under one large dome or roof, forming a chimney or tower.

It is most probable that such a method was adopted in those days, as we find from Nehemiah iii. 11: "Malchijah, the son of Harim, and Hashub, the son of Pahath-moab, repaired the other piece and the tower of the furnaces." This would refer to such a structure which, erected in the plain of Jordan for the temple works, may have continued a sort of national foundry up to the time the Jews were carried captive into Babylon. And again, the restoration and consequent rebuilding of the Temple would require the same operations, and hence the repairing of the furnaces would be a necessary work.

The knowledge of the art of working in metals thus brought into Palestine by the Tyrians at the building of the Temple seems not to have afterwards declined, for we find frequent references in Scripture to works of this kind. In 740 B.C. King Ahaz, visiting King Tiglath-pileser at Damascus, saw an altar which pleased him, and sending Urijah, the priest, a drawing of it, one was made for him exactly similar. In 596 B.C. Nebuchadnezzar, King of Babylon, broke up the bronze pillars, the sea, and the bases of the Temple at Jerusalem, and removed the pieces to Babylon (a work of considerable difficulty) and it follows that probably many of the bronze articles found by Sir H. Layard and others in the ruins of that city may have been made from the bronze of the Temple furniture.

A singular confirmation of the idea that the brass and copper of Scripture are bronze is given by Mr. Edwards in the *Edinburgh Philosophical Magazine*, 1850, where he describes certain relics found near Marazion or Marghazin, one of the oldest towns in Cornwall, leading to the conclusion that the Jews had smelting houses near the shore. The remnants of these smelting pits are still called by tradition Jews' Houses, and the town itself is also called Market Jew, in addition to Marghazin, which means Market Mount; called so, no doubt by the Jews, as the place where the metals were purchased and sold. Possibly the bronze alloy, the mixture of copper and tin, may have been cast here in ingots, and shipped in that form; but this is conjecture.

The bronze of classical antiquity (Greek, *χαλκός;* Latin, *æs*) consisted of copper, with an alloy of one or more of the following metals—tin, lead, silver, zinc; the quantity and character of the alloy chang-

ing with the changing times or different purposes. Amongst existing bronzes, copper varies from 67 to 95 parts. The Phœnicians who traded with the Egyptians would also bring the tin alloy to the Greeks and Romans. Homer calls the metal Kassiteros, and this is equivalent to the Arab word Kasdeer, by which tin is known in the East; it is also called Kastira in Sanscrit. We are enabled from the analysis of coins to arrive at some results as to the admixture of the metals. It thus appears from their coins that the Greeks adhered to a mixture of copper and tin till 400 B.C., after which they used lead. Silver is rare in these coins.

The Romans used lead in their coins, but gradually reduced the quantity, till, under the Emperors Caligula, Nero, Vespasian and Domitian, they coined pure copper, but afterwards reverted to the mixture of lead.

This word χαλκός originally appears to have been the word for pure copper, and is so employed by Homer, who calls ερυθρος (red), αιθωψ (glittering), Φαεννος (shining), terms which will apply to pure copper or the bright alloys of bronze, such as the ancient mirrors were made of.

The old Greek poet describes the process of casting in almost similar terms to those in which it would be poetically described to-day, showing us that the processes then used and now were as nearly as possible alike, and proves the art of working the various substances to have been well understood at that remote period.

The passage referred to is in the "Iliad" of Homer, in the description of the manufacture of the shield of Achilles by the god Vulcan:

Thus having said, the Father of the Fires
To the black labor of his forge retires.
Soon as he bade them blow, the bellows turned
Their own mouths; and where the furnace burned
Resounding breathed; at once the blast expires,
And twenty forges catch at once the fires,
Just as the god directs; now loud, now low,
They raise a tempest or they gently blow.
In hissing flames huge silver bars are rolled,
And stubborn brass, and tin, and solid gold.

Thus the broad shield complete, the artist crowned
With his last hand, and poured the ocean round;
In living silver seemed the waves to roll;
And beat the buckler's verge and bound the whole.

In this description of the casting, Homer uses the word χαλκός, so that we can scarcely tell whether he means copper pure or alloyed. Further, it is more difficult when we read of the mythical Dactyles of Ida in Crete, or the Cyclops, being acquainted with the melting of χαλκός. It is not, however, likely, that the later Greek writers, who knew bronze in its real sense, would have used the word χαλκός without qualification to objects which they had seen, unless they meant it to be taken as bronze.

Pausanais speaks of an old statue he had seen made of separate pieces of metal fastened together with nails, and, using the same word, we understand him to mean bronze, as there exist very early figures of bronze thus made. We read also of the process called "sphyrelaton," being to hammer out the plates and fasten them together with nails. Pausanias also tells that "the Phœnicians pretended that Ulysses dedicated a statue of bronze to Neptune Hippius," but adds that "he does not give credit to the statement, as the art of fusing the metals and casting them in a mould was not then known." "In fact, the first who cast statues were Theodorus and Rhæcus, both natives of Samos."

It has been generally thought that their merit consisted in casting the statues with an inner core, which could be afterwards removed, leaving the castings light, and therefore less costly. But this is open to question, as we have before seen from Assyrian bronzes having been found cast with an inner core of a date older than Theodorus and Rhæcus, and there is now in the British Museum an early Etruscan statuette from Sissa, on the Volturno, with a core of iron.

The Samians were very early noted for their skill in this branch of art, and before the foundation of Cyrene, B.C. 630, they made a bronze vase ornamented with griffins, supported on three colossal figures of bronze, for the Temple of Juno.

The art was known at a very remote period in Italy. Among the Etruscans bronze statues were common before the foundation of Rome, 750 B.C., and Romulus is said to have placed a statue of him-

self, crowned by Victory, in a four-horsed car of bronze, in the new city. Pliny states that "King Numa Pompilius, the immediate successor of Romulus, founded a fraternity of brass founders and bronze workers."

By the Romans a compound was used under the name of "oncalchum" or "auncalchum," which appears to have possessed the composition and properties of brass.

A brazen bull is traditionally said to have been contrived by Pericles at Athens for Phalaris, Tyrant of Agrigentum, 570 B.C. It had an opening in the side, to admit the victims, and a fire was kindled underneath to roast them to death. The throat was so contrived as to make the groans of the victims resemble the roaring of a bull. The artist was made the first experiment, and the tyrant for whom it was made was roasted in it, 549 B.C.

The oldest seat of bronze founding to any extent was the island of Delos, and next to that the island of Ægina. Between these two there existed a rivalry in the times of Myron and Polycletus, of whom the former used the bronze of Delos, the latter that of Ægina. More celebrated than either was the bronze of Corinth, about which it is said "that when Lucius Mummius burnt Corinth, 146 B. C., all the metals in the city melted during the conflagration, and, running together, formed the valuable composition called Corinthian brass. This is exceedingly doubtful, but there may be a spice of truth in it, as long before this period the Corinthian artists had obtained great credit for their method of combining copper with gold and silver. Pliny says of it: "It consisted of gold, silver and copper, and was considered more precious than silver, and little less valuable than gold." There were three kinds of it, varying in color from white to dark yellow.

Corinthian brass appears, for the most part, to have been used for the manufacture of drinking cups and ornamental utensils. The Syriac translation of the Bible says: "Hiram made the vessels for Solomon's Temple of Corinthian brass." Pumps were invented by Ctesibus, of Alexandria, 224 B. C., and were wholly or partially of cast brass or bronze. The most distinguished colossal statue of ancient times was the Colossus of Rhodes, one of the seven wonders of the world. In the days of its prosperity the capital of the island of Rhodes was adorned with over 3,000 statues, but this one exceeded them all. It was erected at the port of Rhodes, in honor of the sun, by Chares of Lindus, a disciple of Lysippus, 290 B. C., or 288 B. C., out of the spoils which Demetrius left behind him when he raised the siege of the city.

It is asserted to have spanned the entrance to the harbor of the island, and to have admitted the passage of vessels in full sail between its wide-spread legs. Its height was about 105 feet, the time taken for its construction was twelve years, and the cost amounted to 300 talents—about £70,000.

This stupendous work was thrown down by an earthquake about 224 B. C., and for nearly nine centuries lay in ruins on the ground. Pliny says: "It was a wonder to behold. Few persons could embrace the thumbs, and the fingers were longer than the bodies of most statues. Through the fractures were seen large cavities, into which large stones had been placed to balance it whilst standing." After the fall of the Roman Empire, when the island of Rhodes was conquered by the general-in-chief of the Caliph Othman, he sold the metal lying on the ground, weighing about 720,900 pounds, to a Jew, who loaded 980 camels in transporting it to Alexandria.

A statue of Zeus, executed at Tarentum 326 B. C. by Lysippus (the master of the maker of the Colossus of Rhodes), was 40 cubits high, and though it could be moved by a touch of the hand, yet resisted the force of storms by a support at the point of greatest stress.

On the number of bronze statues in these ancient times often depended the wealth of a State, cities such as Athens and Delphos having some thousands each.

Of the vast number made by the ancient sculptors nothing but a few fragments remain; but if the colossal head of Venus in the British Museum be taken as a typical example, it will show with what thinness and fineness the figures were cast. Or, again, as an instance of the quality of Greek bronze, the figure of Siris, also in the British Museum, on

which a plate of bronze will be seen beaten out till it reaches the thinness of note paper.

But if the larger works fail, there is an abundance of statuettes, candelabra, mirrors, cestæ and vessels of all kinds, Greek, Roman and Etruscan.

Works in relief (*νόρευμα*), whether beaten out, chased, or cast, are comparatively rare, though this branch of the art was practiced by the greatest sculptors. The Temple of Athene Chalkoites in Sparta had its walls covered with bronze reliefs, but this was an exception to the general rule adopted in the temple decoration.

The greater number of mirrors that exist are Etruscan; a few may be Roman and Greek. But the general rule of their being Etruscan reminds us of the reputation the Etruscans had for the production of works in bronze—not perhaps of high art, but what may be more correctly termed, "industrial art."

They were also celebrated for modeling in clay, and this, according to Pliny, "was the stage of art which immediately preceded casting in bronze, and went hand in hand with it."

The mirrors give the finest examples of patina which we find; in the alloy there seems to have been mixed a considerable quantity of silver in order to obtain a highly reflecting surface.

For articles of furniture the Romans employed Greek artists and workmen. In bronze were made the sellæ, square seats carried about at Roman entertainments; also footstools.

In the excavations made at Pompeii and Herculaneum various works in bronze are found, showing the general adaptation made of bronze by the Romans.

In the theater are bissellii, or chairs of state, made of bronze, and ornamented with silver, for persons of distinction and municipal authorities.

In the tepidarium of the baths are bronze benches, 6 feet by 1 foot, supported by four legs, terminating in the cloven hoofs of the cow, and ornamented at the upper end with heads of the same animal. In the same baths, a brazier of bronze, 7 feet 6 inches by 2 feet 6 inches, supported on cast bronze legs, representing winged sphinxes, terminating in lions' paws. In one of the shops a bronze urn, evidently used for making warm decoctions, and similar to the muller now in use; a bronze mould for making pastry, and a pair of scales—articles of these kinds in addition to the large number of statues and ornamental articles.

In all the bronzes from Pompeii and Herculaneum, the blue color of the patina is very brilliant, although in other bronzes it is more generally some shade of green. This arises from their lying so long in the earth, a difference of soil probably makes a different patina; but something is also due to varieties in the alloy.

Greek seats (*thronoi*) are sculptured on the Parthenon frieze; and sumptuous Greek furniture during the last two centuries B. C. was made of bronze, damascened with gold and silver. It does not appear that the process of gilding bronze was carried to any extent in classical times, except in the production of finger rings, of which a considerable number remain.

During the excavations made in the Palace of Tiberius at Capri, the bronze cock of a reservoir was discovered. As there were conduits of water, and pipes necessarily conveying it to the baths, the knowledge of cock making must have been known and practised, of which this discovery gives a practical proof.

By the time of the Byzantine Empire the power of modeling seems to have declined, and a taste for glittering appearance took its place, and hence the process of ornamenting bronze with reliefs was superseded by inlaying it with silver and other materials.

The art of bronze casting, which has thus sunk during the Byzantine period, was revived with great vigor in Germany in the eleventh century, and there used for the ornamentation of gates and doors of public buildings; notable instances being the bronze gates of the Cathedral of Hildesheim, A. D. 1015, and the column decorated with reliefs on the model of the Trajan Column at Rome, A. D. 1022.

In the twelfth century the art spread southward to Italy, and was at first taken up energetically in lower Italy. But though many interesting works of this date exist—and also from the thirteenth and fourteenth centuries—it was not un-

til the fifteenth century that the art obtained its full mastery. Then the revival of classical art became a real revival under the Florentine artists. Andrea Pisano had made a bronze gate in the Gothic style for the Baptistery of St. John at Florence, 1330 A. D., and in 1401 A. D., the Florentine Council decided to erect another. A competition of artists for the work resulted in the selection of Lorenzo Ghiberti. The contract was entered into with him and his father, November 23, 1403 A. D., and the gates completed and fixed April 24, 1424 A. D. They are truly a magnificent piece of art workmanship, remarkable in several respects as specimens of figure and ornamental modeling of the greatest possible excellence, and which have formed the models in this style for artists of all the following years, and of metal casting which cannot be surpassed.

The subjects of the twenty-eight panels of the gates are from the life of Christ.

On January 2, 1424 A. D., Ghiberti received the commission for the second pair of gates for the same building, and these, containing subjects from the Old Testament, were completed and fixed June 16, 1452 A. D. The Martinengo Tomb, in Brescia, erected about the year 1530 A. D. to Marcantonio Martinengo, though by what artist is unknown, is a fine specimen of this period. The bas-reliefs of bronze are subjects from profane history, and a triumphant procession in bronze adorns the principal frieze.

This development of taste extended to Naples, Rome, Milan, and Venice. Even Raphael designed ornaments for the moulders, of purest taste and most exquisite fancy.

In the sixteenth century it is found carried on with extraordinary skill in Germany at Nuremberg, Augsburg, Munich, and Coburg.

In France also we find the art gaining importance, as may be seen from the bas-reliefs in the Chateau d'Anet, the residence of Diana of Poictiers, which was restored under Philibert de Lorme, 1547–8 A.D., and the monument erected to the memory of Charles VIII., 1499 A.D., around which were figures of the Virtues, executed in gilt bronze. Since then the art of sculpture in bronze may be said to have reverted to nearly its original limits, namely, the production of statues and groups in the round.

In 1699 a bronze equestrian statue of Louis XIV. was erected in the Place Vendome, Paris. This was of gigantic size, containing 60,000 lbs. of bronze. It was demolished during one of the revolutions, 1792 A.D.

The wood furniture during the Renaissance period was decorated and inlaid with brass and bronze. In the eighteenth century we find Ciseleurs mentioned as makers of such brass edgings for furniture.

Perhaps the grandest bronze work of modern times is the colossal statue of Bavaria, completed and inaugurated at Munich, October 3, 1850. This statue was, at the suggestion of King Ludwig, designed by Schwanthaler, the sculptor, and his friend, Lazarini, who modeled the figure under his direction. For the casting it was necessary to melt 20 tons of bronze, a most perilous labor. To give some tangible idea of the size of the figure: In the head or upper part of the bust twenty-five men have found room, in the central part of the figure thirty-five to forty persons could dine, and the space of ground covered by the lower section is enormous in proportion. The figure of this colossal maiden, with the lion by her side, is 54 feet in height—nearly twice the height of the equestrian statue of Wellington, opposite Hyde Park corner.

THEORY OF THE INJECTOR.

By E. HERMANN.

From "Zeitschrift des Oest. Ingenieur-und-Architekten-Vereins," for Abstracts of the Institution of Civil Engineers.

The author considered it desirable to re-examine the theory, although Zeuner has already given the undoubtedly accurate thermodynamic equation applicable to the case. The investigation of the dynamical conditions is wanting in Zeuner, and Grashof's equation gives results differing by 75 per cent. from those ob-

tained experimentally by Villiers. The units assumed are, kilogrammes, kilogrammes per square centimeter, meters, and square meters.

Let M_1=weight of feed-water; M=weight of steam; p_0=pressure in space from which steam is derived; p_1=pressure in steam nozzle; p_2 = pressure in condensation space; p_3 = pressure in space to be supplied (generally $p_3=p_0$; but, on account of the weight of the back-pressure valve, the greatest pressure in the delivery pipe is ξp_3, where $\xi=1.05$); p_4=pressure in space from which feed-water is derived. Generally $p_4=1.03$ kilogramme per square centimeter.

When steady motion is arrived at, the pressure in the section of the steam nozzle is p_1. Then two cases must be distinguished. If p_2, the pressure in the condensation space, is less than $0.577\,p_0$, then $p_1 = 0.577\,p_0$. More rarely p_2 is greater than $0.577\,p_0$, and then $p_1=p_2$. Hence it will be seen that the author proceeds on the assumption that immediately the pressure in the condensation space falls below $0.577\,p_0$, the steam enters it with the velocity due to $0.577\,p_0$ only. The theory is too complicated to be given. It leads to the general result that the ratio of the weight of the feed-water to that of the steam used is given by the equation:

$$\frac{M_1}{M}=\frac{\xi_1\,w_1}{\sqrt{20\,g\,(\xi p_3-p_2)}}-1,$$

where ξ_1 is a co-efficient of correction, to allow for some small quantities neglected, and w_1 is the velocity of the steam in the nozzle. This has been ascertained in a previous investigation of the author, and is given by the equation:

$$w_1=\sqrt{\left\{\frac{2g}{J}\left(t_0+\frac{p_0\,v_0}{C(b+t)}\right)-\left(t_1+\frac{p_1\,v_1}{C\,(b+t_1)}\right)\right.}$$

t_0, p_0, v_0 being the temperature, pressure, and volume, of a kilogramme of steam in the boiler, and t, p, v, the corresponding quantities at the steam nozzle, $C=0.1107$, and $b=187.2$ for steam. The greatest suction height at which the injector will work is found to be:

$$h_{\max}=\frac{p_4-p_2}{0.102}.$$

The theory is then compared with the experiments of Villiers, and the agreement is found to be satisfactory.

The author also gives practical rules for designing an injector for given conditions of pressure and discharge.

ON THE MAINTENANCE OF PURE AIR IN DWELLINGS.*

From "The Builder."

The question of how best to maintain pure air in a house has an important influence in domestic economy, because the health and the vigor of the inmates depend upon their living in a pure atmosphere.

The inhabitants of close rooms, persons who breathe air which has already been breathed, are subject to diseases which may cause death, amongst which may be mentioned pulmonary consumption and certain classes of fevers. But whilst some persons may be killed outright by breathing air which has been polluted by the breath of other persons, the majority are subject to a low condition of health. The reason of this is partly because the oxygen of the air is necessary for keeping in activity the chemical processes which are bound up with life, and that in the act of breathing, that is, in taking air into the lungs, the oxygen in the air is taken up by the lungs and the expelled air is thus deprived of its oxygen; and partly because an individual in expelling the air from his lungs in the act of breathing expels with the air carbonic acid gas, which in large quantities is fatal to life, as well as a large quantity of organic matter, *i. e.*, a portion of his body, which latter has a tendency to putrefy rapidly in stagnant air, and which may thus become a dangerous poison.

Those who live in a close atmosphere

* Paper by Captain Douglas Galton, C.B., F.R.S., ead at the Domestic Economy Congress, Royal Albert all.

have their vital energy impaired; they are less able to perform work. They more nearly approach to the condition of animals in a state of hybernation; they are less able to enjoy life. There is a case mentioned of a dressmaker who employed a large number of women in a very close room at a low rate of wages. Upon a remonstrance being made as to the condition of the atmosphere, ventilation and fresh air were supplied to the room. The women then complained that their wages were insufficient, because in consequence of the fresh air they were so much more hungry and required more to eat. That is to say, their vital energy was increased; and no doubt their capacity for work was much increased also. The same thing occurred when ventilation was introduced into soldiers' barrack rooms, through the efforts of Lord Herbert of Lea. The soldiers complained of the insufficiency of their rations, which had to be supplemented.

Mr. Leeds, a ventilating engineer of New York, mentions an experiment which he made with some flies illustrative of this. He confined a certain number of flies in a bottle full of breathed air and tightly sealed up. He also confined a certain number of flies in a bottle through which he allowed fresh air to circulate. The flies in the bottle filled with pure air were very lively, but they all died in twenty-four hours, as they had no food. The flies in the impure air became at once very stupid and could not fly about, but they lived ten times as long as those in the pure air. And thus we find that many poor people living in unventilated houses exist sometimes to quite an advanced age, but they are often sick and feeble. Therefore, when a person finds he cannot earn his living, or if he does earn it he is sure he cannot get sufficient food to eat, he had better imitate the hybernating animals as nearly as possible, and get into some close, unventilated place, and lie down in perfect quiet and repose, and not fret at all, and he will then be able to get along on very little food. But, if full employment is to be made of their faculties, persons must live in pure air.

Stagnant air can never be pure air. There are being given off perpetually into the atmosphere a number of deleterious substances—the emanations from the breath and other exhalations of every living creature—the emanations arising from the putrefaction of dead creatures or of decaying vegetable substances, the miasma from marshes, &c. These various poisonous emanations are being constantly changed into non-poisonous forms, or burnt up, as it were, by contact with the oxygen of the atmosphere, which is itself being continually renewed from other sources. The movement of the atmosphere facilitates this burning up of the poisonous emanations.

The atmosphere is always in movement. The Registrar-General gives the average movement of air as measured by an anemometer at Greenwich to be about 17 ft. in a second, or 12 miles an hour. It is rarely less than 6 ft. a second, or 6 miles an hour. Thus, if a single indvidual be assumed to occupy a space of 6 ft. high by 1 ft. 6 in. wide, situated in the open air, there would pass through this small space in an hour nearly 200,000 cubic feet of air, even when the movement of outer air is as low as four miles an hour.

In order to maintain purity of air in a house, it is necessary to keep up a continual movement of the air, supplemented by a continual change in the air. This movement and change of air must be maintained without causing a sensation of draught. The science by which this is effected is termed ventilation. It is a science of much simplicity in climates or in weather when the windows and doors can be kept perpetually open; but in this climate, especially in winter, the necessary condition of the avoidance of draughts makes it a very complicated matter, and renders it necessary in providing for a change of air to provide also for warming the inflowing air. The great differences of temperature which occur in this country, moreover, produce numerous other complications.

In considering the question of ventilation, the first question which arises is as to the quantity of fresh air which is required for change of air. If it were desired to supply in a room a volume of fresh air comparable with that supplied out of doors, it would be necessary to change the air of the room from three to six times in every minute; but this would be a practical impossibility. And even if it were possible, it would entail condi-

tions very disagreeable to the occupants, who would have to live in a gale of wind. It is thus evident that in considering the condition of air indoors, we have to seek a standard of admissible impurity in the air, rather than a standard of purity of air comparable with what we have out of doors.

In judging of the amount of impurity which may be allowed in an inhabited air space, the sense of smell, when carefully educated, affords the best indicator of the relative purity and impurity of different kinds of air.

The volume of air which required to maintain the air of a room at a uniform standard varies with the character of emanations given out by the occupants of the room. For instance, the emanations given out by sick persons, and especially those from bad surgical cases, require for their dilution a greater volume of air than is requisite in the case of healthy persons.

Calculations have been made which show that, theoretically, about 3,000 cubic feet of fresh air per hour per individual should be afforded to preserve the air in a confined space at the required degree of freshness; but, in our climate, a careful practical examination of the condition of rooms in barracks and hospitals, judged of by the test of smell, shows that arrangements which appear to provide for a much less amount than that obtained by theoretical calculation, will keep the air of rooms occupied by healthy persons in a fair condition. These results have pointed to about 1,200 cubic feet of air per hour per individual.

This variation from theory seems to be partly due to the fact that there is always a change of air to a certain extent going on in a room. The walls and ceilings themselves allow of a considerable passage of air through them, which is proportioned to the difference between the temperature outside and inside a house, and varies with the materials of which it is constructed. Thus, ordinary bricks are nearly twice as pervious to air as sandstone, and plaster is much more pervious than brick.

If you look at the ceiling, you will see that an old ceiling is blackened where the plaster has nothing over it to check the passage of air, and that where the joists come, and the air has not passed so freely, it is less black. If you break the plaster, you will find that its blackness has arisen from its having acted like a filter, and retained the floating particles of dirt while the air passed through. Ill-fitting doors and windows allow of the passage of a considerable quantity of air.

A sleeping room is very warm at bed time; a rapid fall of temperature outside occurs, and at once a considerable movement of air takes place. The majority of occupiers of sleeping rooms in England close their windows at night; they often block up the chimney by a register or otherwise to prevent the blacks falling. They have no special inlet or outlet for changing the air. In the morning the room would, no doubt, be very close; but if it were not for the continual insensible change arising from the air passing through the walls, doors, and window chinks, &c., the occupants would be asphyxiated. A well-built house unprovided with special means for the inflow of fresh and outflow of vitiated air, is a real source of danger. For these reasons the form, position, and surroundings of a building are important, because the air thus insensibly coming in, as well as all other air admitted, should be taken from pure sources.

Rooms with a large amount of outside wall-space have a better chance of obtaining fresh air than rooms whose walls separate them from other occupied rooms; because the air, filtering in from an occupied room, would necessarily contain more impurities than fresh outside air. The inflow of air to a room takes place not only from all sides, but also from below. The air does not cease where the ground begins, but air permeates the ground, and occupies every space not filled by solid matter or by water. Thus, if you build on a dry, gravelly soil, where the interstices, between the stones are naturally somewhat large, you practically build over a large stratum of air. This air moves in and out of the soil in proportion to barometric pressure, and with reference to the wind.

The fact of this continual free passage of air in and out of the ground makes it important that the ground we live on should be free from impurities. We

might just as well (indeed, probably far better) live over a pig-stye than over a site in which refuse has buried, or in which sewer water has penetrated, or over a soil filled with decaying organic matter; because in cold or damp weather, when the air in the dwelling is warmer than the air outside, the upward movement of this warmer air will draw in air to supply its place from the ground on which the dwelling stands. This movement would be prevented if the whole surface under the dwelling were covered with an impervious material.

It has been the custom of many London builders to lease a site, to remove the valuable gravel and sand, and in order to fill up the hole thus caused, to invite people to deposit rubbish, often including foul garbage, on the site; and when the hole is thus filled up, to build a house over it. People are then astonished at fevers and sickness prevailing in new houses.

The size of a room does not permanently affect the purity of air in the room; that is to say, that the number of occupants in a large room being the same as the number in a small room, the same amount of air admitted and removed will eventually keep the two rooms in the same condition of impurity.

The degree of impurity in the air of an occupied room ultimately depends solely on these two things:

1. The rate at which emanations from the occupants are produced.

2. The rate at which the air of the room is being replaced by fresh air.

The advantage of large space is that the large room is longer in reaching the state of normal impurity than the small room. For instance, the following table shows the time required to bring air to a definite uniform standard of admissable impurity (viz., 0.2 per 1,000 of CO_2) in different sized rooms:

	H.	M.	S.
One man in 10,000 cubic feet.....	3	20	0
" " 5,000 "	1	40	0
" " 1,000 "	0	20	0
" " 600 "	0	12	0
" " 200 "	0	4	0
" " 50 "	0	1	0
" " 30 "	0	0	36

But besides this, the inflow and outflow of air necessary to maintain the standard of impurity is less perceptible in a large than in a small room; for the chief difficulty of keeping ventilation in action arises from the draughts it causes. Every one objects to a current of air which affects him, and desires that if a window is to be opened it shall be situated behind some one else. There is, moreover, in practice, this advantage in the larger rooms, viz., that the larger wall surface and the more numerous windows will allow of a larger insensible ventilation, and thus larger rooms will have an apparently less degree of impurity than small rooms. Although the uniform diffusion of carbonic acid is very rapid in the air of a room, the organic emanations given out do not in practice diffuse themselves either rapidly or uniformly. They hang about in corners where there are obstructions to the flow of air, or near the ceiling. On this account, some space between the occupants of a room is desirable. In sleeping rooms and in hospital wards, and, in fact, in all rooms where the height is above 10 ft. or 12 ft., the floor space becomes of more importance than cubic space. For adults in sleeping rooms it is undesirable to have a floor space for each of less than 50 superficial feet. And the floor space in dormitories in schools should certainly not be less for each boy or girl than a space of 50 superficial feet, or say 10 ft. by 5 ft. or 6 ft. 3 in. by 8 ft. In hospitals, from 90 to 120 superficial feet of floor space is generally afforded; and in fever hospitals, and in surgical wards, much more floor space is frequently desirable.

As before mentioned, the ventilation of a room means the removal of a portion of the air in the room, and the supply of a similar quantity of fresh air to take the place of the vitiated air thus removed.

This change of air may be effected in two ways: 1, by forcing fresh air into the room and allowing this fresh air to displace the air already in the room; or, 2, by drawing the air out of a room and allowing the fresh air to flow in to fill its place. In some cases a combination of both methods is adopted.

The extraction of the air is that which is simplest and most generally adopted. The extraction may be effected by fans or pumping machinery, but the usual system is to depend upon differences of temperature for determining the movement of air. The molecules of air are

but feebly attracted to each other, and increases of temperature or diminutions of pressure separate the particles from one another. Similarly, decreases of temperature bring the particles nearer together, and thus one cubic foot of warm expanded air weighs less than a cubic foot of cold air.

It follows that as warmed air expands it ascends, and as cooled air contracts it falls. It also follows that as the warmed air ascends the air around rushes in to fill its place. Everywhere this heating and cooling of the air is going on; the sun's rays, the proximity of a warm body, the vicinity of a cool shaded surface, all cause movements in the currents of air.

In a room, as air is warmed by the bodies of the occupants, it ascends; it comes against the glass of the windows, cools, and falls down. Draughts felt near the windows are not necessarily air coming in from the window, it may simply be the cooled air falling. It is on this law of the dilatation of air that all the movement of air depends, from the winds and hurricanes to the ventilation of our houses, except where we propel air by fans or other mechanical appliances.

The law which regulates this movement of the air in a confined space or a room, when the temperature is higher than that of the outside air, depends upon the following considerations:

1. Upon the difference of temperature of the air inside the confined space, as compared with that outside.

2. Upon the area of the aperture through which the air passes.

3. Upon the height of the column of ascending air.

Thus velocity of air in a chimney or flue depends on the height of the flue and temperature of the air as it ascends. Therefore, a fire lighted at the bottom of a flue produces a current upwards in the flue. The extraction of air by flues is the plan usually adopted.

The extraction of air by a properly constructed fan, worked by a steam engine, would be more economical than the flue extraction, especially when the warming of the air, which takes the place of that removed, is taken into account; but the strong recommendation of the chimney is its simplicity and its permanence. It requires comparatively little repair, and no skilled labor to look after it. The convenience of this system causes it to be almost universally adopted. The open fireplace is one example of it; the sun-burner is another example; but the system is also applied in every room in which there is an opening at the upper part, out of which the warm air can pass, and an opening below, through which fresh air can flow in. Thus, an ordinary sash window is an example. If the top sash is lowered and the bottom sash raised, the warmed air passes out of the room at the top, and the cooler outer air flows in below.

In the open country air is always in movement. In a town the buildings tend to prevent the rapid circulation of air; and, therefore, the smoke from the houses and the impure emanations from stables, from unclean street surfaces, and from ash pits, hang about and render the air impure.

In a house the space is so sub-divided that air is necessarily stagnant unless special arrangements are made to provide circulation. Of course, in the summer and in warm weather, it is comparatively easy to obtain circulation of air throughout a house, and to fill the house with pure air by opening windows and doors. But in winter and in cold weather or wet weather, when doors and windows are closed, it is necessary to provide special means for creating a circulation of air.

A change of air in a room means that the air in the room which is deteriorated by the breath of the occupants shall be replaced by fresh air. In cold weather it is necessary to provide in some manner for warming this fresh air, or else the temperature of the room would be so lowered as to be injurious.

In most London houses, the ventilation of the room in winter, and the warming of the air, depend on the open fireplace; and there is no better engine for the ventilation of a room. The way in which an ordinary open fireplace acts to create circulation of air in a room with closed doors and windows is as follows: The air is drawn along the floor towards the grate; it is then warmed by the heat which pervades all objects near the fire, and part is carried up the chimney with the smoke, whilst the re-

mainder, partly in consequence of the warmth it has acquired from the fire, and partly owing to the impetus created in its movement towards the fire, flows upwards towards the ceiling near the chimney breast. It passes along the ceiling, and, as it cools in its progress towards the opposite wall, descends to the floor, to be again drawn towards the fireplace. A fireplace is thus powerful enough to draw into the room all the air it wants, and for this purpose will use indiscriminately all other openings, whether inlets or outlets, if necessary.

The rays from the fire pass through the air of the room without warming it; but they warm the surfaces, on which they impinge, of the walls and furniture, and thus communicate the heat to the air. Thus, in a room with an open fireplace, every object in the room contributes its heating surface to warm the air, which is drawn in cold from the outside by the fire.

But the cold air is liable to produce draughts. The only way to prevent draughts is to adopt means for providing fresh warmed air to supply the place of that removed. This may be effected in various ways. The fresh air may be brought to the back of the fireplace and there warmed by some of the spare heat which otherwise would pass up the chimney. By this means each room would be self-contained, so far as its heating and ventilation are concerned. Or, if preferred, a stove may be placed in the basement of a house, and fresh air brought to this stove to be warmed, and then conveyed by flues in the walls to the several rooms, and then admitted in convenient positions; or else the stove may be placed in the staircase or hall of a house, and fresh air be brought to it to be warmed, so that the staircase or hall shall form a reservoir of fresh air, from which the open fires in the several rooms draw supplies of air through the doors or through special openings.

Any of these arrangements will prevent draughts being felt in the rooms. Wherever an open fireplace is used, there should be some arrangement for the supply of fresh warmed air in winter to replace the air carried up the chimney; but as the fire itself warms the walls, and all the articles in the room, by its radiant heat, it is not desirable that this fresh air should be warmed to any great extent. Probably a temperature of 54° to 56° would be ample, as it would soon acquire in each room the supplemental heats which the occupants would desire. The lower the temperature of the fresh air, the larger would be the quantity of oxygen contained in a given bulk of air. Thus, a person breathes on an average when tranquil 16½ cubic feet of air per hour. A cubic foot of dry air at 32° contains 130.375 grains of oxygen, and with the air at 32° he would receive 2,164 grains of oxygen into his system. At 80° temperature, the air contains only 118.7 grains in a cubic foot, and in breathing 16½ cubic feet of air at 80° he would receive into his lungs only 1,971 grains of oxygen, or only about 90 per cent. of the oxygen which he would inhale at the temperature of 32°. Therefore the lower the temperature at which air can be supplied for breathing, consistent with comfort and the avoidance of draught, the better.

There is so great an advantage in the open fireplace as an engine of ventilation for rooms, that although many other and more economical means of heating our rooms have been suggested, it is questionable whether, on the ground of health, it would be wise to give it up.

One great evil from which we suffer in London is the smoke in the atmosphere, and this is aggravated by our open fireplaces, but not necessarily. The smoke is not only an evil in itself, but it aggravates the effect of the fogs which prevail, especially in this country. It seems that the tarry matter given out by the combustion of coal coats over the watery particles which float in the air in time of fog, and thus retards the evaporation, and causes the fogs in towns to be more continuous than they would otherwise be. The fog and smoke are a serious inconvenience to ventilation in London, because ventilation means the supply of pure air. The outside air in London is impure, and the only way to obtain comparatively pure air in the house is to pass the fresh air drawn in through cotton-wool filters. This entails a considerable amount of trouble, as the cotton-wool filter will, in foggy weather, have to be renewed every three or four days. But even on the finest days in London, when the air is what is called clear, it

will be found that the atmosphere is loaded with impurities. There is some smoke, much dust, of which the chief part arises from the enormous amount of horse manure spread over the streets, and many other impurities incidental to a thickly-peopled area. These impurities, and even the fog and smoke over a town such as London, do not rise to any very great height. The tops of the church towers, and of the loftiest houses, have been sometimes observed to be in a clear atmosphere on days when the streets are wrapped in fog. At the level of the tops of such lofty structures a much purer air may always be found than prevails near the street level, and this purer air could be brought down for the supply of houses. In all public buildings in London, especially in the Houses of Parliament, the supply of fresh air should invariably be from this purer source.

But this question should be looked at from a wider standpoint. The population of London, at the beginning of the century, did not exceed 960,000. It is now nearly 4,000,000. Thus a population not much smaller than that of Portugal, which is spread over 34,500 square miles, is concentrated in London on to 118 square miles. The houses spring up on the outskirts of London on every piece of spare land. Each house contributes to the smoke of London, and this smoke-contributing area, and the inhabited area which contributes impurities to the atmosphere, grow more rapidly than the arrangements made for removing the impurities, or for diminishing smoke.

We have had much legislation upon the subject of improving the purity of our rivers and water supply, but pure air is as important to us as pure water, and this question has been practically left untouched. There are Acts of Parliament prohibiting smoke, but, unfortunately, they have been left to be a dead letter, because of the private interests which they assail.

Those who live in the country find the pure air come to them on all sides, because of the constant movement which goes on in the atmosphere. Those who live in London must turn their attention to some method of diminishing the impurities with which London air is charged, or of putting in movement the atmosphere so charged with pollution. The first and most obvious step is to relieve the air from the enormous amount of smoke which is now daily thrown into it, and the next is to remove all refuse from the streets and houses as rapidly as possible. As a contribution towards the well being of the country, each householder should be bound to adopt some method of preventing smoke in his household.

The question of the avoidance of smoke is essentially one which comes under the cognizance of a Domestic Economy Congress, because smoke means waste; the consumption or prevention of smoke is the utilization of waste, because when smoke proceeds from a fire it shows that a large part of the fuel is going away into the atmosphere unconsumed. There have been many suggestions made to prevent smoke—the form of the fireplace, the use of anthracite coal, the use of gas instead of coal, or the use of gas in combination with coal.

One of the first persons who turned his attention to the prevention of smoke was Dr. Arnott. He proposed a fireplace which practically produced no smoke; but it had this inconvenience, that it gave a very dull fire. This inconvenience might, however, be easily remedied by a not very great alteration in the arrangements for admitting air to the top of the fuel.

It would be beyond the limits of this paper to enter upon the very large question of the various forms of grates, or of the other means for preventing smoke, and such a discussion would now be premature, as a committee has been formed for the purpose of testing, in the course of the coming autumn, various new forms of fireplaces devised to prevent smoke.

There is scarcely any question at the present day more important to the inhabitants of London than that of devising means to purify the atmosphere. Parliament can make general laws prohibiting smoke, but the enforcement of the laws must rest with the local authorities. In London, unfortunately, the authorities whose duty it is to enforce the existing law have been very supine in the matter; and London suffers far more than ought to be permitted from the smoke of factories and large chimneys.

As regards the chimneys in private houses, although each gives out only a small quantity of smoke, the aggregate of smoke contributed by them is as serious an element in the pollution of London air as that from the factories. The source of pollution is beyond the reach of present legislation. It is a matter dependent upon the action of each individual householder. The most serious cause of air pollution in each house may be said to be the kitchen chimney, or the chimney of the hot-water apparatus. These must be in operation winter and summer. There are, however, numerous arrangements for cooking and for supplying hot water which do not give out smoke, and which are far more economical of fuel than the ordinary kitchen grate. The use of one or another of these arrangements would entirely abolish smoke from kitchen chimneys, and if kitchen chimneys and fuel used for cooking ceased to give out smoke, the atmosphere of London would be sensibly purer than it now is.

The other cause of impurity in London air—viz., that arising from dust—is more a matter for the local authorities than for the individual householder. The streets should be washed every morning, and swept more than once a day; the dust carts should be covered: dust from dust holes should not be brought up in open baskets and emptied, as it now is, into the open carts, so as to scatter the largest possible amount into the atmosphere, and in the face of the persons passing by; but dust should be daily collected from every house, and received in closed receptacles, to prevent any of it being spread in the atmosphere.

If the local authorities would set themselves seriously to work to prevent the pollution of London air in this direction, and if every individual householder would take the trouble to adopt some method of diminishing the smoke from his own house, a sensible effect would soon be produced on the cleanliness of London and on the purity of its atmosphere.

GAS FOR LIGHT AND HEATING.

By Dr. C. W. SIEMENS, F.R.S.

From the "Journal of the Society of Arts."

WHEN, within the memory of living men, the gas burner took the place of the oil lamp, the improvement was so great that the ultimate condition of perfection appeared to have been reached. It is only in recent years that much attention has been bestowed upon the utilization of by-products with a view of cheapening cost, and that the consumer has become alive to the importance of having a gas of high illuminating power, free from nauseous constituents, such as bisulphide of carbon, thus providing a stimulant for progress on the part of the gas-works manager. This condition of things has been rudely shaken by the introduction of the electric light, which, owing to its greater brilliancy and cheapness, threatens to do for gas what gas did for oil half a century before. The lighting of the City of London and of public halls and works furnishes proof that the electric light is not an imaginary, but a real competitor with gas as an illuminant; and it is indeed time for gas engineers and managers to look seriously to their position with regard to this new rival. For my own part (Dr. Siemens said), I present myself before you both as a rival and a friend—as a rival, because I am one of the promoters of electric illumination; and as a friend, because I have advocated the use of gas for heating purposes during the last 20 years, and am not disposed to relinquish my advocacy of gas both as an illuminating and as a heating agent. Speaking as a gas engineer, I should be disposed to regard the electric light as an incentive to fresh exertion, confidently anticipating achievements by the use of gas which would probably have been long postponed under the continued *regime* of a monopoly. Already we observe, thanks chiefly to Mr. Sugg, both in our thoroughfares and in our apartments, gas burners producing a brighter light than was to be seen previously; and although gas will have

to yield to the electric light the illumination of our lighthouses, halls and great thoroughfares, it will be in a position, I believe, to hold its own as a domestic illuminant, owing to its convenience of usage, and to the facility with which it can be subdivided and regulated. The loss which it is likely to sustain in large applications as an illuminant would be more than compensated by its use as a heating agent, to which the attention of both the producer and the consumer has latterly been largely directed. Having, in the development of the regenerative gas furnace, had opportunities of recognizing the many advantages of gaseous over solid fuel, I ventured, as early as 1863, to propose to the Town Council of Birmingham the establishment of works for the distribution of heating gas throughout the town; and it has occurred to me to take this opportunity (when the gas managers of Great Britain hold their annual meeting at the very place of my early proposal) to lay before them the idea that then guided me, and to suggest a plan of operation for its realization which, at the present day, will not, I hope, be regarded by them as Uptopian. The proposal of 1863 consisted in the establishment of separate mains for the distribution of heating gas to be produced in vertical retorts, that might be shortly described as Appold's coke ovens, heated by means of "producer" gas and "regenerators." The Corporation applied for an Act of Parliament, but did not succeed in obtaining it, owing to the opposition of the gas companies, who pledged themselves to carry out such an undertaking, if found feasible by them. I am ready to admit that at the time the success of the undertaking would have involved considerable difficulties; but I feel confident that the modified plan which it is my present object to bring before you would reduce these difficulties to a minimum, and would open out a new field for the enterprise of those interested in gas works. The gas retort would be the same as at present, and the only change I would advocate in the benches is the use of the regenerative gas furnace. This was first successfully introduced by me at the Paris Gas Works in 1863, and has since found favor with the managers of gas works abroad, and in this country. The advantages that have been proved in favor of this mode of heating are—economy of fuel; greater durability of retorts, owing to the more perfect distribution of heat; the introduction of an additional retort in each bed, in the position previously occupied by the fire grate; and, above all, a more rapid distillation of the coal, resulting in changes of four hours each, whereas six hours are necessary under the ordinary mode of firing. The additional suggestion I have now to make, consists in providing over each bench of retorts two collecting pipes, the one being set aside for illuminating and the other for a separate service of heating gas. I shall be able to prove to you, from unimpeachable evidence, that the gas coming from a retort varies very greatly in its character during progressive periods of the charge; that during the first quarter of an hour after closing the retort the gas given off consists principally of marsh gas and other gases and vapors, which are of little or no use for illuminating purposes; from the end of the first quarter of an hour, for a period of two hours, rich hydro-carbons, such as acetylene and olefiant gas are given off; whereas the gases passing away after this consist for the most part again of marsh gas, possessing low illuminating power. According to the figures given in the experiment of M. Ellissen, President of the French Society of Gas Engineers, it appears that nearly two-thirds of the total production of gas takes place in the above period, while the remaining third is distilled during the first quarter of an hour and the last hour and three-quarters. It hence follows that by changing the direction of the flow of gas at the periods indicated, allowing the first results of distillation to flow into the heating gas main, then for two consecutive hours into the illuminating gas main, and for the remainder of the period again into the heating-gas main, one-third volume of heating and two-thirds of illuminating gas would be obtained, with this important difference, that the illuminating gas would be of 16.16 instead of 13.5 candle power, and that the heating gas, although possessed of an illuminating power of only 11.05 candles, would be preferable to the mixed gas for heating purposes in being less liable in its combustion to deposit soot

upon heat-absorbing surfaces, and in giving, weight for weight, a calorific power superior to olefiant gas. The working out of this plan would involve the mechanical operation of changing the direction of the gas coming from each bench of retorts at the proper periods of the charge. In order to distribute the two gases a double set of gas mains would certainly be required, but these exist already in the principal thoroughfares of many of our great towns, and it would not, I think, be difficult to utilize them for the separate supply of illuminating and heating gas, the latter being only taken into the houses and establishments where it is asked for by the occupiers. The public could well afford to pay an increased price for a gas of greatly increased illuminating power, and the increase of revenue thus produced would enable gas companies to supply heating gas at a proportionately reduced rate. The question may be asked whether a demand would be likely to arise for heating gas similar in amount to that for illuminating gas; and I am of opinion that, although the present amount of gas supplied for illuminating purposes exceeds that for heating, the diminution in price for the latter would very soon indeed reverse these proportions. Already gas is used in rapidly increasing quantities for kitcheners, for the working of gas engines, and for fire grates. As regards the latter application, I may here mention that an arrangement for using gas and coke jointly in an open fireplace combined with a simple contrivance for effecting the combustion of the gas by heated air, has found favor with many of the leading grate builders and with the public. As regards the use of illuminating gas, I have one more suggestion to make, which I feel confident will be viewed by you with interest. The illuminating effect produced in a gas flame depends partly upon the amount of carbon developed in the solid condition in the body of the flame, and partly upon the temperature to which these particles are heated in the act of combustion. Having shown how by separation a gas of greater luminosity may be supplied, it remains to be seen how the temperature of combustion may be raised. This may be effected by certain mechanical arrangements, whereby a portion of the waste heat produced by the flame itself is rendered available to heat the gas and air sustaining the combustion of the flame—say to 600° Fahrenheit, or even beyond this point. The arrangement I have adopted for this purpose is a burner of the ordinary Argand type, mounted in a small cylindrical chamber of sheet copper, connected with a vertical rod of copper, projecting upwards through the center of the burner, and terminating in a cup-like extension at a point about four inches above the gas orifices, or on a level with the top of the flame. A small mass of fire-clay fills the cup, projecting upwards from it in a rounded and pointed form. The copper vessel surrounding the burner is contracted at its upper extremity with a view of directing a current of air against the gas jets on the burner, and on its circumference it is perforated for the admission of atmospheric air. The bottom surface is formed of a perforated disc covered with wire gauze, and wire gauze also surrounds the circumference of the perforated cylinder. The external air is heated in passing through these "regenerative" surfaces, and the flame is thus fed with air, heated to the point above indicated, which, by more elaborate arrangements, might be raised to a still higher degree. The ball of fire clay in the center of the burner, which is heated to redness, serves the useful purpose of completing the combustion of the gas, and thus diminishes the liability to blackening of the ceiling. The arrangement for transferring the heat from the tip of the flame to the air supporting its combustion was applicable also to an open bat's-wing burner, but I have not yet had time to ascertain accurately the amount of increase of luminosity that may be realized with this class of burner. From a purely theoretical point of view, it can be shown that of the caloric energy developed in the combustion of gas a proportion (probably not exceeding 1 per cent.) is really utilized in the production of luminous rays; and that even in the electric light nine-tenths of the energy set up in the arc is dispersed in the form of heat, and one-tenth only is utilized in the form of luminous rays. It would lead us too far here to go into the particulars of these calculations, but it is important to call attention to them in order to show the large margin still before us

for practical improvements. I may here mention that another solution of the problem of heating the incoming air by the waste heat of the products of combustion has lately been brought under public notice by my brother, Frederick Siemens, which differs essentially from the plan I have suggested, inasmuch as he draws the flame downwards through heating apparatus, and thence into a chimney. In practice both these methods of intensifying a gas flame will probably find independent application, according to circumstances. By the combined employment of the process for separating the illumination from the heated gas, with the arrangement for intensifying the luminosity of the gas flame, the total luminous effect produced by a given consumption of coal gas may, according to the figures given, be increased threefold, thus showing that the deleterious effects now appertaining to gas illumination are not inseparable from its use. My principal object in preparing this communication has been to call your attention generally to the important question of an improved gas illumination, and more particularly to the subject of a separate supply for heating gas, which, if carried into effect, would lead, I am convinced, to beneficial results, the importance of which, both to gas companies and to the public, it would be difficult to over-estimate.

ON THE PROGRESS AND DEVELOPMENT OF THE MARINE ENGINE.*

From "The Engineer."

The author began by referring to a paper read at the Liverpool meeting in 1872, by Mr. F. J. Bramwell, F.R.S., on "The Progress Effected in Economy of Fuel in Steam Navigation, considered in Relation to Compound Cylinder Engines, and High-pressure Steam;" then proceeded to continue the subject from the date of that meeting, to trace out whether any, and if so what, progress had been made; further, to consider whether or no we have reached the finality so strongly deprecated by Sir Frederick Bramwell in the discussion referred to, and if not, then in what direction we are to look for further development.

From a table it would seem that the steam pressures are now much higher, the boilers have less heating surface, and the cylinders are much smaller for the indicated horse-power developed, than in 1872; and at the same time the average consumption of fuel is reduced from 2.11 lbs. to 1.828 lbs., or by 13.38 per cent. The author then briefly described the modern marine engine and boiler. The three great types of compound engines may be placed as follows in the order of their general acceptance by the ship-owning community: (1) The two-cylinder intermediate-receiver compound engine, having cranks at right angles. (2) The Woolf engine in the tandem form, having generally the high-pressure and low-pressure cylinders in line with each other, but occasionally alongside, and always communicating their power to one crank. Such a pair of engines is used sometimes singly, oftener two pairs together, working side by side to cranks at right angles; recently three pairs together, working to cranks placed 120 deg. apart. The system affords the opportunity of adding yet more engines to the same propeller to an indefinite extent. (3) The three-cylinder intermediate-receiver compound engine, with one high and two low-pressure cylinders, the steam passing from the high-pressure cylinder into the receiver, and thence into the two low-pressure cylinders respectively. The cranks are placed at equal angles apart round the crank shaft, so as to balance the forces exerted upon the shaft. These three types may be said to embrace all the engines now being manufactured in this country for the propulsion of steam vessels by the screw propeller. In their leading principles they also embrace nearly all paddle engines now being built, whether the cylinders be oscillating, fixed vertically, or inclined to the shaft. The compound engine in fact, in one of these three

* A paper read before the Institution of Mechanical Engineers, by Mr. F. C. Marshall.

forms, may now be said to be universally adopted in this country; and the question of the relative value of simple expansion in one cylinder, and of compound expansion in two or more cylinders, which agitated the minds of some of our leading engineers ten years ago, is now practically solved in favor of the latter. The marine boiler of to-day is in all its main features the same as it was ten years ago. The single-ended boiler, made with two, three, and sometimes four furnaces, is the simplest form, and for all powers under 500-indicated horsepower is the most generally adopted. The double-ended form is largely used. It has been found more economically efficient than the single-ended form, by as much as 10 per cent. in the writer's own experience. It is generally adopted for engines of large power, but for small power is inconvenient, owing to its occupying more room lengthwise in the vessel, and also involving two stokeholds and therefore more supervision. At one time great difficulty was found in keeping the bottoms of boilers of this kind tight. Owing to their length, the unequal expansion due to different temperatures at the top and bottom caused severe racking strains on the bottom seams and riveting—so severe in some cases as to rend the plating for a large part of the bottom circumference of the shell. This difficulty has now been to a large extent got over, in consequence of the greater attention given to the form and direction of the water spaces in the boiler itself, so as to induce circulation of water; the introduction of the feedwater at the top instead of near the bottom; the more careful management now usual on the part of engineers; and lastly, the use of larger plates, welded horizontal seams, drilled rivet holes, and more perfect workmanship throughout. A modification of double-ended boiler is that introduced by Mr. Alfred Holt. It has many decided advantages, but is costly to make. The formation of the two ends into separate fire-boxes leaves the bottom of the boiler free to adapt itself to the variations of temperature to which it is exposed. The separation of the furnaces from the combustion chamber, excepting through the opening afforded by a connecting tube, is an advantage in the same direction, and avoids almost entirely the racking strains due to irregular furnace action. The weight of water carried is less, and that of the boiler may also be made less; while the elliptical form of the two ends gives greater steam space. A type of boiler largely used in her Majesty's Navy, somewhat like a locomotive boiler, is highly efficient in regard to weight and power developed. Many examples have yielded one indicated horse-power in the cylinders for every three square feet of heating surface, under natural draught and with a very moderate height of funnel; and this with a consumption of fuel not exceeding 2½ lbs. per indicated horsepower per hour under a working pressure of 60 lbs. With the aid of a steam jet in the funnel, the heating surface per indicated horse-power has fallen below 2½ square feet. The large water surface afforded for escape of steam secures almost entire freedom from priming, without the incumbrance of steam domes; and the large combustion chamber allows of the thorough combustion of the gases before their passage through the tubes. The locomotive type of boiler has lately occupied the writer's attention, with a view to its more definite introduction into marine work. The difficulties however which lie in the way of applying it to steamers going long voyages are very great. The principal difficulty lies in the necessity of burning a large quantity of fuel in a very limited space and time. This can only be done either by direct pressure or exhaust action applied at the furnace. In other words, we must either exhaust the funnel, which will absorb a large amount of power, but would be comparatively easy of application; or our stokers, as is the case with our miners, must work under a pressure of air. The writer stated that his experience in the manufacture and working of steel boilers was satisfactory. Many steel boilers of sizes varying from 6 feet diameter to 14 feet 6 inches diameter have left the works at St. Peter's since 1877, when the first was made; and in no case has there been a failure of a plate after being put into a boiler, either in the process of manufacture or in working at sea. The mode of working is as follows: For shell plates, from ⅝ in. to ⅞ in. thick, to warm each to a dark red heat before rolling, having previously

drilled a few holes to template for bolting the strakes together; the longitudinal seams are usually lap joints. treble riveted, requiring the corners to be thinned, which is done after rolling. The furnace plates are generally welded two plates in length, and flanged to form Adamson rings, and at the back end to meet the tube plate; the back flame box plates are flanged, also the tube plates and front and back plates, and wherever work is put on to the plate it is annealed before going into the place. The rivet holes are drilled throughout. In the putting together the longitudinal seams of the thicker plates of the shells, great care is always taken to set the upper and under plates for the lap to their proper angle before they are bolted together, a point generally overlooked by the practical boilersmith. The question of corrosion is one which is gradually being answered as time goes on; and so far very satisfactorily for steel. Some steel boilers were examined a few weeks ago which were amongst the first made; and the superintending engineer reports, "There is no sign of pitting or corrosion in any part of the boiler; the boilers are washed out very carefully every voyage, and very carefully examined, and I cannot trace anything either leaking or eating away. No zinc is used, only care in washing out, drying out, and managing the water." This is the evidence of an engineer with a large number of vessels in his charge. On the other hand, some of our most prominent Liverpool engineers always use zinc, and take care to apply it most strictly. The evidence of one of them is as follows: "We always fix slabs of zinc to most boilers, exposing not less than a surface of one square foot for every twenty indicated horse-power, and distributed throughout the boiler. This zinc we find to be in a state of oxide and crumbling away in about three months. We then renew the whole, and find this will last twelve months or more, when it is renewed again. Meanwhile we have no pitting and no corrosion; but, on the contrary, the interior surfaces appear to have taken a coating of oxide of zinc all over, and we have no trouble with them." Then the writer considered our present marine engine as to its efficiency and capability of further improvement. The weight of machinery, water and fuel carried for propelling ships has not had due attention in the general practice of engineers. By the best shipping authorities the writer is assured that every ton of dead weight capacity is worth on an average £10 per annum as earning freight. Assuming, therefore, the weight of the machinery and water of any ordinary vessel to be 300 tons, and that, by careful design and judicious use of materials, the engineer can reduce it by 100 tons, without increasing the cost of working, he makes the vessel worth £1,000 per annum more to her owners. That there is much room for improvement in this direction is shown by the following statement, giving, for various classes of ships, the average weight of machinery, including engines, boilers, water, and all fittings ready for sea, in pounds, per indicated horse power;

	lb. per I. H. P
Merchant steamers	480
Royal Navy	300
Engines especially designed for light draught vessels	280
Royal Navy, Polyphemus class, (given by Mr. Wright)	180
Modern locomotive	140
Torpedo vessels	60
Ordinary marine boilers, including water	196
Locomotive boilers, including water	60

The ordinary marine boiler, encumbered as it is by the regulations of the Board of Trade and of Lloyd's Committee, does not admit of much reduction in the weight of material or of water carried when working. The introduction of steel has reduced the weight by about one-tenth; but it will be the alteration of form to the locomotive, tubulous, or some other type, combined with some method of forced draught, to which we must look for such reductions in weight of material and water as will be of any great commercial value. The engine may be reduced in weight by reducing its size, and this can only be done by increasing the number of revolutions per minute. It has hitherto been the practice to treat the propeller as dependent upon the size of engines, draught of water, and speed required. This process should be reversed. The propeller's diameter depends on the column of water behind, necessary to overcome the

resistance in front of it due to the properties of the vessel. This fixed, the speed will then fix the number of revolutions, which will be found much greater than is usual in practice; and from this the size of the engines and boilers will be determined. Great saving in weight can be effected by careful design and judicious selection and adaptation of materials; also by the substitution of trussed framing and a proper mode of securing the engine to the structure of the vessel, as worked out in H. M. S. Nelson, by Mr. A. C. Kirk, of Glasgow, and in the beautifully designed engines by Mr. Thornycroft, in place of the massive cast iron bedplates and columns of the ordinary engines of commerce. The same may be said of the moving parts. In fine, the hull and engines should be as much as possible one structure; rigidity in one place and elasticity in others is the cause of most of the accidents so costly to the shipowner; under such conditions mass and solidity cease to be virtues, and the sooner their place is taken by careful design, and the use of the smallest weight of material—of the very best kind for the purpose—consistent with thorough efficiency, the better for all concerned. Coming to the question of the consumption of fuel, a considerable saving has been effected in nine years, as shown in the following table:

Item.	1872.	1881.
Working pressure, lb. per sq. in.	52.5	77.4
Heating surface per I.H.P. sq. ft.	4.64	3.919
Piston speed, feet per min.....	376	467
Coal burnt per I.H.P., lbs.....	2.11	1.828

This shows a saving equal to 13.38 per cent. in quantity of fuel consumed. Mr. Marshall then read a letter from Mr. Alfred Holt, of Liverpool, bearing on this subject, in which Mr. Holt spoke favorably of the single-crank engine, and stated his belief that the compound system would ere long be abandoned for the simple engine. He is endeavoring to feel his way to using the steam in one cylinder only, and so far the results have been encouraging; and he is now fitting a 2200-ton vessel on that system. He is also endeavoring to do without a crank shaft, the forward end of the screw shaft carrying an ordinary crank with overhung pin. This experiment also promises satisfactorily. In his opinion the great improvement of the immediate future is to increase the steam production of our boilers. A ton weight of a locomotive boiler produces as much steam as 6 tons of an ordinary steamboat boiler. Mr. Holt speaks of the coal account as one of the minor disbursements of a steamer. He does not give the ratio which coals bear to the total disbursements, but from other reliable sources Mr. Marshall found that, according to the direction of the voyage, it varies from 16 to 20 per cent.—or, say, an average of 18 per cent.—of the total disbursements, in a vessel carrying a cargo of 2500 tons. This will represent to day about £3000 per annum, and in 1872, at equal prices, the cost would have been £3750—showing a saving of £750, equal to a dividend of, say, 3 per cent. on the value of the ship. Again, the cost of coal per mile run for such a vessel in 1872 would have been at least 16½d.; to-day it does not exceed 13d. The marine boiler as now made is very efficient, but if the quantity of steam used be considered, in relation to the increased pressure, it will be seen that the boiler of to-day is little if any more efficient than that of ten years ago. The present boiler has an evaporative efficiency of about 75 per cent. and cannot be much improved so long as air is supplied to the furnace by the natural draught. To increase the efficiency from 75 to 82.5 per cent. would require about double the heating surface, the weight of boiler and water being also doubled, while the gain would only be 10 per cent. Mr. Blechynden's formula, used in Mr. Marshall's works for weights of cylindrical marine boilers of the ordinary type, and for pressures varying from 50 lbs. to 150 lbs., is as follows:

$$W=\frac{(P+15)\ (S+D^2L)}{C};$$

$$\text{or } W=\frac{2S\,(P+15)}{C}$$

when $S=D^2L$, which is a common proportion.

Here W=weight in tons.
P=working pressure as on gauge.
S=heating surface, in square feet.
D=diameter in feet.
L=length, in feet.

C=a constant divisor, depending on the class of riveting, &c. For boilers to Lloyd's rules, and with iron shells having 75 per cent. strength of solid plate, C=13,200.

This formula, if correct—and it is almost strictly so—would give the relative weight of boilers per sq. ft. of heating surface, for 105 lbs. and 150 lbs. total pressure, assuming we wish to increase the efficiency 10 per cent. as follows:

$$\text{Weight at 105 lbs.}=105\times\frac{1}{C}$$

$$\text{“} \quad 150 \quad \text{“} =150\times\frac{1.75}{C}=\frac{263}{C}$$

$$\text{Hence the ratio of weight}=\frac{263}{105}=2.5$$

In other words the boiler with the higher efficiency would weigh two and a-half times that with the lower efficiency. In the case of a vessel of 3000 tons, with engines and boilers of 1500 indicated horse power, the introduction of locomotive boilers with forced draught would place at the disposal of the owner 150 tons of cargo space, representing £1500 per annum in addition to the present earnings of such a vessel.

Mr. Thornycroft has for some years used the locomotive form of boiler for his steam launches, working them under an air pressure—produced by a fan discharging into a closed stokehold—of from 1-in. to 6-ins. of water, as may be required. The experiments made gave an evaporation of 7.61 lbs., of water from 1 lb. of coal at 212° Fah., with 2in. of water pressure, and 6.41 lbs. with 6 in. of pressure. These results are low; but it is to be remembered that the heating surface is necessarily small, in order to save weight, and the temperature of the funnel consequently high, ranging from 1073° at the first pressure and 1444° at the 6-in. With the ordinary proportions of locomotive practice the efficiency can be made equal to the best marine boiler, when working under the water pressure usual in locomotives, say from 3-in. to 4-in. including funnel draught. It has fallen to the lot of writer to fit three vessels recently with boilers worked under pressure in closed stokeholds. The results, even under unfavorable conditions, were very satisfactory. The pressure of air would be represented by 2 ins. of water, and the indicated horse-power given out by the engines was 2800, as against 1875 when working by natural draught, or exactly 50 per cent. gain in power developed.

Mr. Marshall then proceeded to refute the arguments which may be urged against the use of the locomotive boiler at sea, and which we need not reproduce. Coming to the engines, Mr. Marshall said that the total working pressure of to-day may be accepted as 105 lbs., or equal to seven atmospheres. If it were boldly accepted that eleven atmospheres, or 165 lbs., were to be the standard working pressure, the result would be a gain of 14.55 per cent., provided no counteracting influence came into play. Of course, there are forces which war against the attainment of the full extent of this advantage, viz., the greater condensation in the cylinders and loss in the receiver or passages. In regard to the former, it may be questioned whether by steam jacketing the high-pressure cylinder, correctly proportioning the steam passages, and giving a due amount of compression in both cylinders, this may not be reduced far below the generally received notion; and the latter cause of loss may be considerably reduced in its effect by a more carefully chosen cylinder ratio. The ratio usually adopted, between 3.5 and 4 to 1, whether the pressure be 70 lbs. or 90 lbs., may well be questioned. With a cylinder ratio of 2.95 to 1, the economic performance is very good, and equal to any with the higher ratio. A lower cylinder ratio has another advantage of considerable value, viz., that the working pressure can be much reduced as the boilers get older, while by giving a greater amount of steam the power may be maintained—at an extra cost of steam, of course, but not so great a cost as with higher ratios. The cut-off in the high-pressure cylinder usually takes place at about 0.6, and the ratio of expansion has decided the ratio of cylinders. The use of separate starting valves in both cylinders obviates that necessity. The difficulties in the way of taking advantage of the higher economic properties of greater pressures than hitherto used on board ship, are, it is submitted, not insuperable, and it would be to the interest of all that they should be firmly and determin-

edly met. It may be accepted as an average result that the Woolf engine, as usually arranged, will use 10 per cent. more steam than the receiver engine for the same power. Of the three-cylinder receiver type the data are insufficient to form a definite opinion upon; but so far the general working of the Arizona is stated to be as good, economically, as any of the two cylinder receiver class. The surface condenser remains as it was ten years ago, with scarcely a detail altered. In most engines it remains a portion of the framing, and as such adds greatly to the weight of the engine. It is a question seriously worth consideration whether or no the surface of tubes can be reduced. The practice at present is to make the surface one-half the boiler surface as a minimum, that is, equal to about 2 square feet per indicated horse-power. In practice, the writer has found 1.4 square feet per indicated horse-power to maintain a steady vacuum of 27½ in.

Mr. Marshall has just completed six pairs of engines for three twin screw ships, having steel shafts of 10 in. diameter, and has in each case run the engines at 120 revolutions per minute, while indicating 1380 horse-power from each pair for ten to fifteen hours without stopping; and in no case has a single bearing or crank pin warmed or had water applied, the surface on examination being perfect. In these engines all working bolts, pins, and rods, except the piston and connecting rods, are of steel, all rods in tension being loaded to 8,000 lbs. per square inch. The boilers are of the Navy type, made throughout of Simens-Martin steel plates, riveted with steel rivets, all holes drilled. Furnaces are welded and flanged; the tubes are of brass. In comparison with an ordinary merchant steamer's iron boilers of the double-ended type, they weigh, including water and all appurtenances, as follows:

	Double-ended Type.		Navy Type.
Weight, tons......	135	..	146
I.H.P...............	1,400	..	2,760
Draught...........	Natural	...	Forced

The screw propeller is still to a great extent an unsolved problem. We have no definite rule by which we can fix the most important factor of the whole, namely, the diameter. Mr. Froude has pointed out that by reducing the diameter, and thus the peripheral friction, we can increase the efficiency; and this is confirmed by cases—of Iris reduced 2 ft. 3 in., and the Arizona reduced 2 ft. This must of course be qualified by other considerations. The ship has by her form a definite resistance, and a certain speed is required; if the propeller be made too small in diameter, the ship will not be driven at the required speed, except at serious loss in other directions. This question was too large and complicated to be dealt with here, and should, in the first instance, be made the subject of careful and extended experiment, on which a separate paper should be written.

To sum up the whole: Progress has been made during the past nine years, and in the following particulars: (1) The power of the engines made and making show a great increase. (2) Speeds hitherto unattainable are now seen to be possible in vessels of all the various classes. (3) The consumption of fuel is reduced by 13.38 per cent. on the average; and numbers of vessels are now working on much less coal than that average, while the quality of the coal is in nearly all cases very inferior, so that it is not unfair to take credit for 20 per cent. reduction. (4) The working pressures of steam are much increased on the average, and still are increasing; many steamers now being built for 120 lbs. per square inch, while 90 lbs. is the standard pressure now required.

A New Air Pump.—The Pnéole is the name given to an ingenious pneumatic pump recently invented and described to the Academy of Sciences by M. F. de Romilly. It consists of a closed chamber or cylinder communicating by a side pipe with the receiver to be exhausted. In the top and bottom of the chamber two pipes project with their orifices opposite each other. The bottom pipe leads to a cistern, and a jet of water or other liquid is launched through it with considerable velocity by any convenient device, such as M. de Romilly's water elevator. This jet throws itself into the mouth of the pipe which projects from the roof of the chamber, and as this mouth is wider than the diameter of the jet, the water carries a considerable number of air bubbles with it from the chamber. Owing to their lightness these bubbles cannot return again, but must either follow the water which is led by a return pipe back to the cistern, or escape by means of a vent provided for them above the chamber. In this way the air within the chamber is drawn out and the receiver exhausted.

DETERMINATION OF THE EFFICIENCY OF LARGE CYLINDRICAL IRON TANKS.

By JOHN D. CREHORE.

Contributed to VAN NOSTRAND'S ENGINEERING MAGAZINE.

SOMETIME in the spring of 1868, in Cleveland, Ohio, a new wrought-iron tank 60 feet in diameter, and filled with water to the height of 18 feet, burst and fell asunder. The thickness of the single-riveted sheets composing this tank did not exceed three-sixteenths of an inch.

On the 29th of June, 1881, at Cincinnati, Ohio, a new iron water tank 48 feet in height and 100 feet in diameter, burst at a point 12 feet or more from the bottom and fell asunder, when filled to the estimated depth of about 40 feet. The riveted plates of which this tank was made, ranged in thickness from half an inch at bottom to a quarter of an inch at top, as stated in *Engineering News* of July 9th, 1881.

It would seem from the continued recurrence of such failures, that there is need of reiterating the teachings of the standard treatises on applied mechanics, or of emphasizing, to parties interested, the necessity of having the right specifications made before constructing; and of insisting upon carrying out such specifications strictly in honest execution.

Not having the actual complete data required for determining the strength of these two particular tanks, I give the ordinary mode of finding the requisite thickness of both single-riveted and double-riveted plates used in the construction of cylindrical tanks with vertical axes; and then apply the general expression to two cases where the diameters are 60 feet and 100 feet respectively.

Take 62.425 lbs. = weight of one cubic foot of water.

" .0361256 lbs. = weight of one cubic inch of water.

r=radius of cylinder base.

x=depth of water measured from surface.

Then the divellent force, due to water pressure, upon any elementary portion, or ring, of the height dx; is

$$dP=.0361256\times 2rxdx.$$

Therefore, after integrating between limits 0 and P, 0 and x, we have

$$P=.0361256rx^2, \quad . \quad . \quad . \quad . \quad (1)$$

which is the total force for the depth x, tending to send the sheets along any two diametrically opposite elements of the cylindrical surface.

But since this divellent force, for a given diameter, at a given point, varies with the height of water above that point, we have the simple formula

$$p=.0361256\times 2rx, \text{ lbs.} \quad . \quad . \quad . \quad (2)$$

which is the intensity of bursting force at any depth x, if r and x are in inches.

For the inch of depth next above the point x, we find from equation (1)

$$\begin{aligned}\Delta P&=.0361256\, r[x^2-(x-1)^2]\\&=.0361256\, r(2x-1)\end{aligned} \quad . \quad . \quad . \quad . \quad (3)$$

as the total divellent force for that inch. Now, since equation (2) gives the intensity at the bottom of this inch, it should be used instead of equation (3).

To resist the force p, of the water, we have for each inch of the depth, two plates of the thickness t inches each, and able to sustain with safety a tension of T pounds to the square inch of cross section. Therefore,

$$p=.0361256\times 2rx=2tT, \text{ lbs.} \quad . \quad . \quad (4)$$

$$t=\frac{.0361256rx}{T}, \text{ inches,} \quad . \quad . \quad . \quad (5)$$

It is plain that the safe allowed inch-strain, T, depends upon the quality of iron, the mode of riveting, and the workmanship thereof. Following with Rankine, the ordinary rules for riveted work to resist steam or water, we take:

"Diameter of a rivet for plates less than half an inch thick, about double the thickness of the plate.

"For plates half an inch thick and upwards, about once and a half the thickness of the plate."

Calling the ultimate resistance of good iron plates, to tension, equal to the ulti-

mate resistance of rivet-iron to shearing, we ought to have, for single-riveted sheets, $ct-2r_1t=\pi r_1^2$

$$c=2r_1+\frac{\pi r_1^2}{t}, \quad . \quad . \quad . \quad . \quad (6)$$

where $c=$ distance between centers of consecutive rivets in a row,
$r_1=$ semi-diameter of a rivet,
$t=$ thickness of a plate,
all in inches.

For double-riveted sheets,

$$c=2r_1+\frac{2\pi r_1^2}{t}, \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

When the sheets are less than half an inch thick, we have $r_1=t$, and equation (6) becomes

$$c=t(2+3.1416)=5.1416\,t, \quad . \quad . \quad . \quad (8)$$

for single-riveted joints; and

$$c=t(2+6.2832)=8.2832\,t, \quad . \quad . \quad . \quad (9)$$

for double-riveted joints.

When the sheets are half an inch thick and upwards, $2r_1=\frac{3}{2}t$, $r_1=\frac{3}{4}t$,

$$c=t(1.5+\tfrac{9}{16}\pi)=3.2671\,t, \quad . \quad . \quad . \quad (10)$$

for single-riveted joints; and

$$c=t(1.5+\tfrac{9}{8}\pi)=5.0343\,t, \quad . \quad . \quad . \quad (11)$$

for double-riveted joints.

The plates are weakened by the simple removal of iron from the rivet holes, in the ratio

$$\frac{c-2r_1}{c}=\frac{\pi r_1^2}{2r_1t+\pi r_1^2}=\frac{3.1416}{5.1416}, \quad . \quad . \quad . \quad (12)$$

$$\therefore \quad T_1=15,000\times\frac{3.1416}{5.1416}=9.165,$$

for single-riveted sheets less than half an inch thick. And

$$\frac{c-2r_1}{c}=\frac{3.1416}{5.8082}, \quad . \quad . \quad . \quad (13)$$

$$T_1=15,000\times\frac{3.1416}{5.8082}=8,113,$$

thickness one-half inch or more.

Similarly, for double-riveted plates, the value of T is virtually reduced in the ratio

$$\frac{c-2r_1}{c}=\frac{2\pi r_1^2}{2r_1t+2\pi r_1^2}=\frac{3.1416}{4.1416} \quad . \quad . \quad . \quad (14)$$

$$\therefore \quad T_1=15,000\times\frac{3.1416}{4.1416}=11,379,$$

when $r_1=t$, and $t<\frac{1}{2}$ an inch.

But when $r_1=\frac{4}{3}t$, and t is not less than half an inch, T is virtually reduced in the ratio

$$\frac{c-2r_1}{c}=\frac{3.1416}{4.4749}, \quad . \quad . \quad . \quad (15)$$

$$\therefore \quad T_1=15000\times\frac{3.1416}{4.4749}=10.532.$$

The value of T, here taken for perfect unpunched plates, is one-fourth of 90,000 lbs., the assumed ultimate resistance of the iron as specified, thus rendering the so-called "factor of safety" equal to 4; whereas, in fact, 15,000 lbs. is doubtless a strain beyond one-half of that at the elastic limits, so that the real factor of safety here does not exceed 2.

From the *Cincinnati Commercial* of July 1, 1881, I quote the following extracts from the specifications for the large tank:

"The tank to be composed of twelve (12) rings of the best quality of fibrous boiler-iron plates, of a tensile strength of 60,000 pounds to the square inch. The annexed tables give the required thickness and weight of iron in pounds per square foot, and also the number, length, width and area for all the plates for the bottom of tank and for each ring in the circumference of the tank."

"All the vertical joints in the first six (6) rings of plates from the bottom upwards, to the double-riveted, known as "staggered" riveting; the remainder of the six (6) vertical joints as well as the horizontal joints in the bottom of the tank, to be riveted with a single row of rivets. The diameter, length and pitch of rivets corresponding to the thickness of plates, and width of laps for joints, are given in the annexed Table, No. 3."

As no tables are given, I am unable to assign the actual thickness of the plates, except as above stated in *Engineering News.*

I have therefore assumed, in case of the Cincinnati tank, that the thickness of plates varied uniformly from $\frac{1}{2}$ an inch at bottom to $\frac{1}{4}$ inch at top; and for the Cleveland tank have given the greatest, and probably uniform, thickness of $\frac{3}{16}$ of an inch.

Some local reporters of the disaster at Cincinnati call the burst reservoir a "steel" tank; but, as the specifications call for iron, I presume the contractors did not substitute steel.

Computing the required thickness, t, of the plates, by equation (5), the following table results:

Depth of water in feet. x	Radius of tank in feet. r	Kind of Riveting.	T=15,000 lbs., and within elastic limit.		T=30,000 lbs., and beyond elastic limit.		Supposed actual thickness.
			T_1	Thickness of iron. t.	T_1	Thickness of iron. t.	
0	50	Single.	9,165	0. inches.	18,330	0. inches.	.25 inches.
4	"	"	"	0.114 "	"	0.0570 "	.2708 "
8	"	"	"	0.227 "	"	0.1135 "	.2917 "
12	"	"	"	0.341 "	"	0.1705 "	.3125 "
16	"	"	"	0.454 "	"	0.2270 "	.3333 "
20	"	"	8,133	0.640 "	"	0.3200 "	.3541 "
24	"	"	"	0.768 "	"	0.3840 "	.3750 "
28	"	Double.	10,532	0.691 "	22,758	0.3200 "	.3958 "
32	"	"	"	0.790 "	"	0.3657 "	.4167 "
36	"	"	"	0.889 "	"	0.4114 "	.4375 "
40	"	"	"	0.988 "	"	0.4572 "	.4583 "
44	"	"	"	1.087 "	"	0.5029 "	.4792 "
48	"	"	"	1.185 "	"	0.5486 "	.5000 "
0	30	Single.	9,165	0. "	18,330	0. "	.1875 "
4	"	"	"	0.0681 "	"	0.0341 "	" "
8	"	"	"	0.1362 "	"	0.0681 "	" "
12	"	"	"	0.2043 "	"	0.1022 "	" "
16	"	"	"	0.2724 "	"	0.1362 "	" "
20	"	"	"	0.3406 "	"	0.1703 "	" "

It is apparent from my table, above given, that neither of these tanks gave a margin of safety so large as I have assumed. For having taken T=15,000, and the so-called factor of safety=4, the Cincinnati tank would fail to give this factor, with 20 feet of water, and the Cleveland tank would fail to give this factor with 12 feet of water.

Again, calling T=30,000, that is, the nominal factor of safety=2, but really taxing the iron beyond its elastic limit, the Cincinnati tank would fail to yield this factor at the center before being entirely filled; and the Cleveland tank would cease to give the factor 2 at the depth of 24 feet.

Now, all this assumes what is probably never completely realized in practice, viz.:

1. That the tensile strength of the plates, before punching, is 60,000 lbs. to the square inch of section.

2. That the remaining cross section of a plate, after the rivet holes have been punched, is equal to the cross section of the rivets.

3. That the rivets under their initial longitudinal strain, are still capable of sustaining sheering stress equal to the tensile strength of the plates.

4. That punching does not unfavorably affect the strength of the iron between the rivet holes.

5. That the distribution of strain is uniform on the remainder of plate, between two consecutive rivets.

6. That all rivets fill their holes and are perfect.

7. That the rivet holes are exactly opposite in the two plates, so that no "drifting" is required.

Taking into consideration all these things, it is easy to see how a so-called factor of safety of two, straining the iron past its elastic limit, would be used up, with consequent disaster.

Of course the thickness of plates near the top should be greater than the values of t found by the formula, and not less than the supposed actual values in the table. Although the pressure is greatest on the lowest rings, yet, owing to its connection with the bottom, failure occurs above this ring. Large high tanks should be properly braced and stiffened to resist the action of wind.

In Forbes' "Tourists" the capacity of the larger European churches and cathedrals is given as below: St. Peter's Church, Rome, holds 54,000; St. Paul's, London, 35,000; St. Sophia's, Constantinople, 33,000; Florence Cathedral, 24,300; St. Petronius, Bologna, 24,000; St. Paul's, Rome, 32,000; St. John Lateran, 22,900; Notre Dame, Paris, 20,000; the Pisa Cathedral, 13,000; St. Stephen's, Vienna, 12,400; St. Dominico's, Bologna, 12,000; St. Peter's, Bologna, 11,500; Cathedral of Venice, 11,000; Milan Cathedral, 7,000. These figures do not refer to seating capacity.

THE ACTUAL LATERAL PRESSURE OF EARTHWORK.

By BENJAMIN BAKER, M. Inst. C.E.

Proceedings of the Institution of Civil Engineers.

I.

The fact that a mass of earthwork tends to assume a definite slope, and that if this tendency be resisted by a wall or any other retaining structure, a lateral pressure of notable severity will be exerted by the earthwork on that structure, must have enforced itself upon the attention of constructors in the earliest ages. Many of the rudest fortresses doubtless had revetments, and of the hundreds of topes, or sacred mounds, raised in India and Afghanistan two thousand years ago, not a few afford examples of surcharged retaining walls on as large a scale as those occurring in modern railway practice. Nevertheless, long as the subject has occupied the attention of constructors, there is probably none other regarding which there exists the same lack of exact experimental data, and the same apparent indifference as to supplying this want. Thousands of pieces of wood have been broken in all parts of the world to determine the transverse strength of timber, whilst the experiments that have been undertaken to ascertain the actual lateral pressure of Earthwork are hardly worth enumerating. One authority after another has simply evaded the task of experimental investigation, by assuming that some of the elements affecting the stability of earthwork are so uncertain in their operation as to justify their rejection, and have so relieved themselves from further trouble. It would hardly be less logical to assume that because timber is liable to become rotten and possesses no strength at all, it was therefore unnecessary to conduct experiments in that case also. As a matter of fact, although these uncertain elements are neglected in investigations, engineers in designing, and still more contractors in executing, works, do not neglect them, nor could they do so without leading to a blameworthy waste of money in some instances, and to a discreditable failure in others. The result of the present want of experimental data is then simply that individual judgment has to be exercised in each instance, without that aid from careful experimental investigation which in these times is enjoyed in almost every other branch of engineering.

The mass of existent literature on the subject is both misleading and disappointing, for with little exception the bulk of it consists merely of arithmetical changes rung upon a century-old theory, which even at the time of its inception was put forward but as a provisional approximation of the truth, pending the acquirement of the necessary data. Writing some fifty years ago Professor Barlow excused his "very imperfect sketch of the theory of revetments, at least as relates to its practical application," on the ground that there was a "want of the proper experimental data;" and but comparatively the other day Professor Rankine had to write in almost identical terms: "There is a mathematical theory of the combined action of friction and adhesion in earth; but for want of precise experimental data its practical utility is doubtful." It is not, therefore, for want of asking that the missing data are not forthcoming. Indeed, the present desiderata could not have been more clearly formulated than they were half a century ago by Professor Barlow in the following words: "To render the theory complete, with respect to its practical application, it is necessary to institute a course of experiments upon a large scale; upon the force with which different soils tend to slide down when erected into the form of banks. A well-conducted set of experiments of this kind would blend into one what many writers have divided into several distinct data. Thus some authors have considered first, what they call the natural slope of different soils, by which they mean the slope that the surface will assume when thrown loosely in a heap; very different, as they sup-

pose, from the slope that a bank will assume that has been supported, but of which that support has been removed or overthrown. This, therefore, leads to the consideration of the friction and cohesion of soils, and what is denominated the slope of maximum thrust; but, however well this may answer the purpose of making a display of analytical transformations, I cannot think it is at all calculated to obtain any useful practical results. I should conceive that a set of experiments, made upon the absolute thrust of different soils, which would include or blend all these data in one general result, would be much more useful, as furnishing less causes of error, and rendering the dependent computations much more simple and intelligible to those who are commonly interested in such deductions."

A knowledge, however imperfect, of the actual lateral pressure of earthwork, as distinguished from what may be termed the "text-book" pressures, which, with hardly an exception known to the author, are based upon calculations that disregard the most vital elements existent in fact, is of the utmost importance to the engineer and contractor. It affects not merely the stability of retaining walls, but the strength of tunnel linings, the timbering of shafts, headings, tunnels, deep trenches for retaining walls, and many other works of every-day practice. The vast divergence between fact and theory has perhaps impressed itself with peculiar force upon the author, because, having had the privilege of being associated with Mr. Fowler, Past President of the Inst. C.E., during the whole period of the construction of the "underground" system of railways, he has had the advantage of the experience gained in constructing about 9 miles of retaining walls, and, in relation to the subject of the present paper, the still more valuable experience of 34 miles of deep-timbered trenches for retaining walls, sewers, covered ways, and other structures. A timber waling is a sort of spring, rough it may be, but still the deflections when taken over a sufficiently large number of walings afford an approximate indication of the pressure sustained—an advantage which a retaining wall does not possess. Again, though numberless retaining walls have failed, in ninety-nine cases out of hundred the failures have been due to faulty foundations, and, consequently, experiences of this sort seldom afford any direct evidence as to the actual lateral pressure of earthwork. In timbered trenches, on the other hand, the element of sinking and sliding foundations does not so frequently arise to complicate the investigation.

All kinds of earth were traversed by the above 34 miles of trenches, from light vegetable refuse to the semi-fluid yellow clay, which at different times has crushed in so many tunnel linings in the northern districts of the metropolis. The heights of the retaining walls ranged up to 45 feet, the depths of the timbered trenches to 54 feet, and the ground at the back of the former was in many cases loaded with buildings ranging up to 80 feet in height. Possibly some of the author's observations and conclusions in connection with these and other works of a similar character may be of interest to engineers, though the information he is able to contribute, having been obtained chiefly in the ordinary routine of his practice and not in specially devised investigations, must necessarily form but a very imperfect contribution to the data which have been asked for so long.

The theory underlying all the multitudinous published tables of required thickness for retaining walls is, that the lateral pressure exerted by a bank of earth with a horizontal top is simply that due to the wedge-shaped mass, included between the vertical back of the wall and a line bisecting the angle between the vertical and the slope of repose of the material. If this were true in practice, all such problems could be solved by merely drawing a line on the annexed diagram, in which *a b d c* is a square, *a b g* a triangle, having the sides of the ratio of $1 : \sqrt{\frac{1}{3}}$, and *a h d* a parabolic curve.*

Thus, if it were required to know the lateral pressure per square foot of earth-

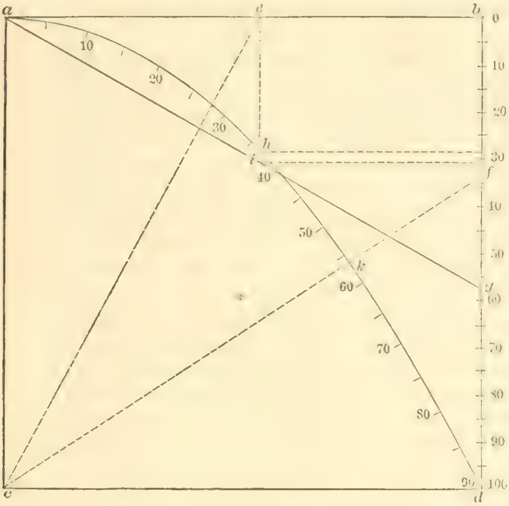
---

*For earthwork and masonry of the same weight per cubic foot the equation for stability is:

$$\frac{ht^2}{2} = \frac{h^3}{6} \tan^2 \tfrac{1}{2} \text{ angle.}$$

Hence, the required thickness (t_1) in terms of the height (h) will be $t_1 = \sqrt{\tfrac{1}{3}} \tan \tfrac{1}{2}$ angle, which is represented on the diagram by the line $a-g$; and the "equivalent fluid pressure" in terms of that of a cubic foot earthwork will be $= \tan^2 \tfrac{1}{2}$ angle, which is represented by the parabolic curve *a h d*.

work, having a slope of repose of $1\frac{1}{2}$: 1, and the thickness of rectangular vertical wall which, when turning over on its outside edge would just balance that pressure, it would merely be necessary to draw the line $c\ f$ at the given slope of



$1\frac{1}{2}$: 1 and the line $c\ e$ bisecting the angle $a\ c\ k$, when the line $e\ h$ would give the equivalent fluid pressure in terms of that of a cubic foot of the earth=28.7 per cent., and the line $e\ i$ the thickness of the rectangular wall in terms of the height=31 per cent, the weight of masonry being the same as that of the earth.

Common stocks in mortar and ballast backing each weigh about 100 lbs. per cubic foot, hence, on the preceding hypothesis, the pressure acting on the wall wolud be the same as that due to a fluid weighing 28.7 lbs. per cubic foot. If, as is usually the case, the masonry be heavier than the earthwork, the required thickness of wall would be reduced in inverse proportion to the square root of the respective weights, so that should the masonry weigh 10 per cent. more than the ballast, the thickness would be about 5 per cent. less than before, or, say, 29.5 per cent. of the height.

For other slopes of repose the equivalent fluid pressure and thickness of wall for materials of equal weight would be as follows:

Ratio of horizontal to vertical......	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3
Fluid pressure......	5.6	7.7	10	12.4	14.8	17.2	19.6	22	24.3
Thickness...........	.136	.160	.182	.203	.222	.239	.256	.27	.284
Ratio of horizontal to vertical......	1.4	1.5	1.6	1.7	1.8	2	3	4	8
Fluid pressure......	26.5	28.7	30.7	32.8	34.6	38.2	52	61	100
Thickness...........	.297	.31	.32	.33	.34	.357	.416	.451	.578

In the thickness tabulated above no allowance has been made for the crushing action on the outer edge; in practice the batter usually given to the face of the wall more than compensates for this action if the mean thickness be that given in the table. No factor of safety is included, but according to theory the wall in each case would be just on the balance. Any one accustomed to deal with works of this class will, however, know that in practice walls so proportioned would in the majority of cases possess a large factor of safety.

Doubtless many engineers will, with the author, have noticed that laborers and others not infrequently carry out unconsciously a number of valuable and suggestive experiments on The Actual Lateral Pressure of Earthwork. In stacking materials, rough-and-ready retaining walls, made of loose blocks of the same material, are often run up, and as it is generally of little moment whether a slip occurs or not, the workmen do not trouble about factors of safety, but expend the least amount of labor that their every-day experience will justify, and so a tolerably close measure is obtained of the average actual pressure of material retained. When the wood paving was recently laid in Regent

Street, the space being limited, the stacked wooden blocks in many cases had to do duty as retaining walls to hold up the broken stone ballast required for the concrete substructure. In one instance (Ex. 1) the author noted that a wall of pitch-pine blocks, 4 feet high and 1 foot thick, sustained the vertical face of a bank of old macadam materials which had been broken up, screened, and tossed against this wall until the bank had attained a height of 3 feet 9 inches, a width at the top of about 5 feet, and slopes on the farther sides deviating little from 1.2 to 1. Now, referring to the diagram and table of thickness, it will be seen that according to the ordinary theory the thickness of wall which would just balance the thrust of a bank 3 feet 9 inches high of material having a slope of repose of 1.2 to 1 would be $3.75 \times .27 = 1.01$, or, say, 1 foot, which is the actual thickness of the given wall. But in the table the specific weight of the material in the wall and backing is assumed to be the same, whereas in the present case the weight of the pitch-pine block wall, allowing for the height being greater than that of the bank, would only be, say, 46 lbs. $\times \dfrac{4 \text{ feet}}{3.75 \text{ feet}} = 49$ lbs. per cubic foot, whilst that of the broken granite bank would be, say, 168 lbs. less 40 per cent. for interstices = 101 lbs. per cubic foot. It follows, since the wooden wall stood, that if it had been made of materials having the same weight per cubic foot as the bank, the retaining wall would not have been on the point of toppling over, as the ordinary theory would indicate, but have possessed a factor of safety of at least $\dfrac{101 \text{ lbs.}}{49 \text{ lbs.}}$, or, say, 2 to 1. The effective lateral pressure of the earthwork in this instance consequently could not have exceeded a fluid pressure of $\dfrac{22 \text{ lbs.} \times 49}{101} = 10.7$ lbs. per cubic foot, instead of the 22 lbs., which theoretically corresponds to the given slope of 1.2 to 1.

Taking another case, in which the wall, instead of being lighter than the bank, was much heavier, the same conclusion still holds good. In this instance (Ex. 2) the author found a wall of slag blocks having a batter of $\frac{1}{5}$ of the height, and an effective thickness of 1 foot sustained a bank of broken slag 10 feet high, with a surcharge of some 5 feet more. The battering wall, with a thickness of $\frac{1}{10}$ of the height, would have the same stability as a vertical wall 0.173 thick, and the lateral pressure of the surcharged bank with the battering face would be practically the same as that of a horizontal-topped bank with a vertical face; hence, since the relatively closely-packed slag blocks constituting the wall would weigh about 40 per cent. more than the broken slag of the bank, the thickness of a vertical wall built of materials of the same weight as the bank, and having the same stability as the wall under consideration would be $= \sqrt{1.4} \times 0.173 = 0.205$ of the height. Referring to the table, the figure 0.205 will be found to apply to a slope of repose of 0.8 to 1, whereas the actual slope in the instance of this slag was 1.33 to 1. For the latter slope the thickness theoretically should have been 0.29, and since the stability varies as the square of the thickness, it follows that with the thickness indicated by theory, the wall, instead of being just on the balance, would have possessed a factor of safety of at least $\dfrac{0.29^2}{0.205^2}$, or 2 to 1, as in the last example.

Other instances of these unintentional experiments on the lateral pressure of earthwork will be found in the stacking of coal in station yards, in the rubbish banks at quarries, and in many other instances which have been investigated by the author, with the invariable result of finding that walls which, according to current theory, would be on the point of failure, really possess a considerable factor of safety.

Turning now from indirect to direct experiments, specially arranged with a view to determine the lateral pressure of earthwork, those carried out at Chatham nearly forty years ago by Lieutenant Hope, R.E., may be referred to. His intention was to experiment first with fine dry sand, as free as possible from the complications introduced by cohesion, irregularities of mass and other practical conditions, and then to extend the investigation to ordinary shingle, and to clay and other soils possessed of great

tenacity. Sand and shingle were, however, alone experimented with.

The direct lateral thrust of sand weighing 91 lbs. per cubic foot when lightly thrown together, and $98\frac{1}{2}$ lbs. when well shaken, was measured by balancing the pressure exerted on a board 1 foot square. The mean results of seven experiments (Ex. 3) was 9 lbs. 7 oz., which is that due to a fluid weighing nearly 19 lbs. per cubic foot. As the slope of repose of the sand employed was 1.42 to 1, the theoretical fluid pressure due to the weight of $98\frac{1}{2}$ lbs. per cubic foot would be 26.2 lbs., or about 40 per cent. more than the observed 19 lbs. per cubic foot.

With gravel (Ex. 4) weighing $95\frac{1}{2}$ lbs. per cubic foot, and having a slope of repose of $1\frac{1}{3}$ to 1, about the same lateral pressure was found to exist. Lieutenant Hope attempted to reconcile the difference between theoretical and actual results by adding to the measured force an estimated sum for friction against the sides of the apparatus, but experiments of the author's to be subsequently referred to, clearly prove that the difference is not to be so accounted for. Indeed, the knowledge of what the pressure theoretically should be would appear to have given Lieutenant Hope an unconscious bias in the direction of rather exaggerating the experimental results. This it is extremely easy to do, as a trifling amount of vibration will alter the pressure from 10 to 50 per cent., and a comparatively innocent shake in a small model will correspond in its relative effects with an earthquake in real life.

Experiments with colored sand in a vessel with glass sides did not uniformly confirm the usual theory that the angle of pressure of maximum thrust is half that contained between the natural slope and the back of the wall (Ex. 5). Thus the line of separation was at an angle of 24° with the vertical instead of 28°. Again, with a gravel bank (Ex. 6) 10 feet high the line of separation ranged from 3 feet 8 inches to 5 feet 8 inches from the back of the wall, whilst as the natural slope was $1\frac{1}{3}$ to 1, the distance should have been 5 feet in all instances if Coulomb's theory applied strictly to even such exceptionally favorable materials as dry sand and shingle.

The really valuable portion of Lieutenant Hope's investigation was the series of experiments on walls built of bricks laid in wet sand. The first of these (Ex. 7) was about 20 feet long and two-and-a-half bricks, or say, 1 foot 11 inches thick. When raised to a height of 8 feet and backed with ballast, it had inclined from the vertical about $1\frac{1}{2}$ inch; at 9 feet the inclination had increased to $3\frac{1}{4}$ inches, and at 10 feet the wall fell forward in one mass. At the instant when the thrust of the ballast overcame the stability of the wall, the overhang must have been 4 inches, and the moment of stability per lineal foot certainly not more than 2,000 lbs. $\times$ 0.9 foot $=$ 1,800 foot-pounds. Hence, dividing by $\frac{h^3}{6}$, is obtained 10.8 lbs. per cubic foot as the weight of the fluid, which would have exerted a lateral pressure equal to that of the ballast piled against this 10-feet wall. This is hardly more than half the pressure obtained with the 1-foot square board, and shows how desirable it is that even the most faithful experimenter should not know what to expect if a mere shake of a table will enable him to obtain the desired result. The natural slope of the ballast being $1\frac{1}{3}$ to 1, and the weight $95\frac{1}{2}$ lbs. per cubic foot, the pressure theoretically should have been 23.6 lbs. per cubic foot instead of 10.8 lbs.; hence a wall so proportioned as to be on the point of toppling over, according to the ordinary theory, would in this instance have had a factor of safety of rather more than 2 to 1.

Another vertical wall (Ex. 8) was constructed with the same amount of materials differently disposed. At 8 feet high, after heavy rain, the 18-inch thick panel between the 27-inch deep counterforts had bulged $1\frac{1}{4}$ inch; at 12 feet 10 inches the bulging had increased to $4\frac{1}{2}$ inches, and the overhang at the top to $7\frac{1}{2}$ inches, when, after some hours' gradual movement, the wall fell. The moment of stability at the time of failure could not have exceeded 2,600 lbs. $\times$ 1 foot $=$ 2,600 foot-pounds, which, divided by $\frac{h^3}{6}$, gives 7.4 lbs. per cubic foot, instead of the theoretical 23.6 lbs., as the weight of the equivalent fluid. This result is clearly not evidence that the pressure of the ballast was less in the counterforted

wall than in the wall of uniform thickness, but that the binding of the ballast between the counterforts increased the stability of the wall by practically adding somewhat to its weight.

A wall with a batter of $\frac{1}{5}$ of the height, and with counterforts of the same thickness as the last (Ex. 9), was next tried, with noteworthy results. This wall, only 18 inches thick, with counterforts 3 feet 9 inches deep, measuring from the face of the wall, and 10 feet apart, was carried to a height of 21 feet 6 inches without any indications of movement, beyond a bulging about halfway up of $2\frac{1}{2}$ inches at the panel, and $1\frac{1}{2}$ inch at the counterfort; and in Lieutenant Hope's opinion it would probably have stood for years without giving way any more, although the mean thickness was less than $\frac{1}{10}$ of the height. The calculated stability indicates that a fluid pressure of 8.5 lbs. per cubic foot would have overturned the wall, and, correcting for the reduced thrust of the ballast due to the batter of its face, the equivalent pressure on a vertical wall would be that of a fluid weighing 10 lbs. per cubic foot.

Here, again, doubtless the binding of the gravel between the counterforts contributed to the stability of the wall; but, even adopting the extreme and impossible hypothesis that the ballast was as good as so much brickwork, or, in other words, that the wall was a monolithic structure of the uniform thickness of 3 feet 9 inches, its stability would barely balance the 23.6 lbs. per cubic foot fluid pressure theoretically due to the weight and slope of repose of the backing. Assuming that the binding of the ballast between the counterforts increased the stability, as in Examples 8 and 9, by about 45 per cent., the fluid resistance would be 14.5 lbs. per cubic foot; and, remembering that this wall did not fall, though the bricks were only laid in sand, it is reasonable to infer that this interesting experiment confirms the previous conclusion that a properly built wall in mortar or cement, just balancing the theoretical pressure, would really have had a factor of safety of 2 to 1. Other experiments of Lieutentant Hope's justify this inference, and so do the experiments of General Pasley, also made at Chatham many years ago.

General Pasley experimented with loose dry shingle weighing 89 lbs. per cubic foot, and having a natural slope of $1\frac{1}{4}$ to 1. His model retaining walls (Ex. 10) were 3 feet long, 26 inches high, of various forms and thickness, and weighed 84 lbs. per cubic foot. The stability of each wall was tried by pulling it over by weights before and after backing it up with shingle, and the difference between the two pulls of course represented the thrust of the shingle. When the thickness of the vertical wall was 8 inches, the stability, without shingle, was equivalent to a pull of 47 lbs. applied at the top of the wall, and with shingle, the pull required to upset it was reduced to 30 lbs. The difference of 17 lbs. represents the thrust of the shingle, and throughout the several hundreds of experiments this appears to have been comprised within the limits of 16 lbs and 24 lbs. The center of pressure being at $\frac{1}{3}$ of the height of the wall, the mean thrust of 20 lbs. at the top will be equivalent to 60 lbs. at the center of pressure, and the area being 6.5 square feet, and the height 26 inches, the actual lateral pressure of the shingle, as deduced from General Pasley's experiments, is equivalent to that of a fluid weighing 8.5 lbs. per cubic foot, instead of 21 lbs. as theory would indicate.

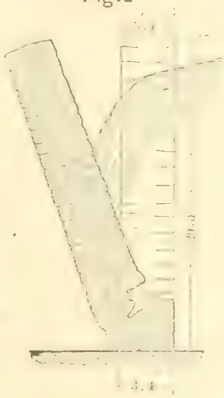
General Cunningham tested some model revetments, and his experiments led him to believe that General Pasley had overestimated the thickness required for stability. The models, in this case about 30 inches in height, were weighted with earth and musket bullets to the equivalent of an equal mass of masonry weighing 129 lbs. per cubic foot. One of the models (Ex. 11) represented a wall 30 feet high, 6 feet thick at the base, vertical at the back, battering 1 in 10 on the face, with counterforts 4 feet 3 inches thick, 18 feet from center to center, and of a depth equal to the thickness of the wall or, say, 3 feet at the top and 6 feet at the base. This was backed up and surcharged with shingle weighing 104 lbs. per cubic foot, but required a pull of 111 lbs. to overturn it. Another model (Ex. 12) representing a wall 18 feet high, 4 feet 4 inches thick at the base, and 2 feet 8 inches thick at the coping, without counterforts, when surcharged with shingle to a height greater than that of the wall, required a

pull of 84 lbs. to upset it. A fluid pressure of 19 lbs. per cubic foot would overcome the stability of such a wall; hence, having regard to the surcharge and to the pull, it will be found that the actual lateral pressure of the shingle could not have exceeded that due to a fluid weighing 8 lbs. per cubic foot.

General Burgoyne also commenced an experimental investigation of the question of retaining walls, but circumstances precluded his pursuing the subject. About half a century ago he built at Kingstown four experimental walls 20 feet long and 20 feet high, having the same mean thickness of 3 feet 4 inches, or $\frac{1}{6}$ of the height, but differing otherwise. One of them (Ex. 13) was of the uniform thickness of 3 feet 4 inches, and battered $\frac{1}{5}$ of the height; another (Ex. 14) was 1 foot 4 inches thick at the top, and 5 feet 4 inches at the bottom, with a vertical back; the third (Ex. 15, Fig. 1) was of

Fig. 1

Fig. 2



the same dimensions, with a vertical front; and the last (Ex. 16, Fig. 2) was a plain rectangular vertical wall 3 feet 4 inches thick. The masonry consisted simply of rough granite blocks laid dry, and the filling was of loose earth filled in at random, without ramming or other precautions, during a very wet winter. No. 1 wall stood perfectly, as might have been expected from the behavior of Lieutenant Hope's experimental wall of nearly the same height and batter. No. 2 wall also stood well, coming over only about 2 inches at the top. A fluid pressure of 22.5 lbs. per cubic foot would be required to overcome the stability of this dry masonry wall weighing 142 lbs. per cubic foot. Earthwork of the class described, consolidated during continuous rain, would not weigh less than 112 lbs. per cubic foot, nor have a slope of repose less than $1\frac{1}{2}$ to 1. Referring to the table, the theoretical pressure of such earthwork would be $28.67 \times 1.12 = 32$ lbs. per cubic foot, or nearly one-half greater than the wall could resist.

No. 3 and No. 4 walls both fell when the filling had attained a height of 17 feet. The former came over 10 inches at the top, was greatly convex on the face, overhanging 5 inches in the first 5 feet of its height and rending it in every direction, when finally it burst out at 5 feet 6 inches from the base, and about two-thirds of the upper portion of the wall descended vertically until it reached and crushed into the ground (Fig. 1). The vertical wall tilted over gradually to 18 inches and then broke across, as it were, at about $\frac{1}{4}$ of its height and fell forward (Fig. 2). So long as the wall remained vertical the calculated stability would indicate it to be equal to sustain the pressure of a fluid weighing 20.4 lbs. per cubic foot, but the overhang of 18 inches and the bulging which occurred would reduce the stability exactly one-half, so that a fluid pressure of 10.2 lbs. would really have sufficed to effect the final overthrow. The character of the failure both of No. 3 and No. 4 walls clearly indicates that if the walls had been in mortar or cement, as usual, the overhang would not have been a fraction of that occurring with the dry stone walling, and the failure would not have taken place. Since, as already stated, the theoretical thrust of the earthwork would be 32lbs. per cubic foot, it is hardly unfair to conclude that a wall in mortar and proportional to that pressure would not have come over and would have enjoyed a factor of safety of at least 2 to 1.

Colonel Michon carried out in 1863 an interesting experiment (Ex. 17) on a 40 feet high retaining wall of a peculiar type (Figs. 3 and 4), which, perhaps, may be best described as a very thin wall with numerous battering buttresses turned upside down. The face wall, battering 1 in 20, was only 1 foot 8 inches thick, and the buttresses, spaced about 5 feet apart from center to center, were also 1 foot 8 inches thick by 2 feet 4 inches

deep at the base and 9 feet 2 inches at the top. The work was hurriedly constructed during continuous rains with any stones that came to hand, and with very bad lime. When the filling had attained a height of 29 feet the wall bulged a trifle, but no further movement was noticed, though the filling, when carried up to the top of the coping, was allowed some weeks to settle in the

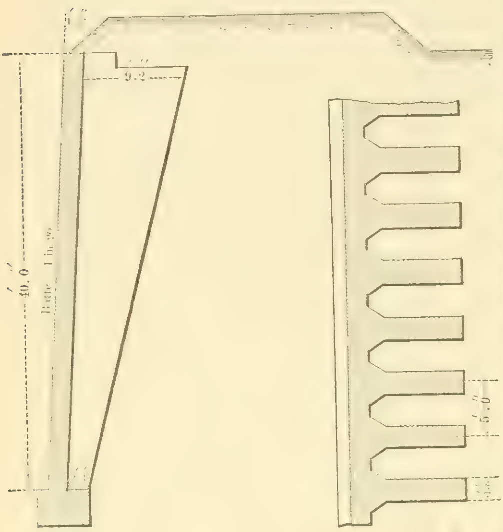


Fig.3 Fig.4

rain. Earth was then piled above the level of the coping to a height of between 3 and 4 feet, when the wall fell. The fall was preceded by a general dislocation of the masonry at the base, a bulging at about one-third of the height, and a slight movement of the top towards the bank. The lower portion of the wall fell outwards, the upper part dropped vertically (as in General Burgoyne's wall, Fig. 1), and a considerable number of the counterforts went forward with the slip and even maintained their vertical position.

This failure arose from a flexure of the thin wall at the center of pressure of the earthwork, and would not have occurred had the masonry been in cement instead of in weak unset lime. No direct data therefor are afforded for an exact estimate of the actual lateral thrust of the heavy wet filling on this lofty wall. Nevertheless, as the weight of the masonry was only 18,000 lbs. per lineal foot, and the center of gravity of the same from the toe but 6 feet 6 inches, it follows that the wall, even if monolithic, would be overturned with the pressure of a fluid weighing 11 lbs. per cubic foot. How far the sodden earthwork between the counterforts contributed to the stability of the wall is open to question, but it could hardly account for the difference between the 11 lbs. or less stability and the 32 lbs. due, according to the ordinary theory, to the weight and slope of the backing. If dirt were as good as masonry, General Burgoyne's wall with the battering back (Fig. 1) would have been more stable than the vertical wall (Fig. 2) in the ratio of the squares of their respective bases, or, say, as $2\frac{1}{2}$ to 1, whereas, these walls proved to be of equal stability, both falling with 17 feet of filling. Colonel Michon, by assuming dirt to be as good as masonry, and a wall 40 feet high and 1 foot 8 inches thick of unselected stones and unset mortar to be as good as a monolith, succeeds in reconciling the behavior of his wall with the ordinary theory of the stability of earthwork; but in the author's experience the conditions assumed are not approached in practice. The stability of this lofty wall battering only $\frac{1}{20}$ of the height on the face, and averaging hardly more than $\frac{1}{12}$ of the height in thickness, is, nevertheless, one of the most remarkable and interesting facts connected with the subject of the present paper.

To show how invariably an experimentalist is driven to the same conclusion as to the excess in the theoretical estimate of the pressure of earthwork, the "toy" experiments of Mr. Casimer Constable with little wooden bricks and peas for filling may be usually referred to. The peas took a slope of 1.9 to 1, and weighed twice as much per cubic foot as the wooden retaining wall. By the table the thickness of wall, which would just balance the lateral pressure would be $.35\sqrt{2}=.49$ height. By experiment, a wall (Ex. 18) having a thickness of .40 height moved over slightly, but took some amount of jarring to bring it down. Since the stability varies as the square of the thickness, the calculated wall would be 50 per cent. more stable than the actual wall, without considering the question of jarring. If the

slope of the peas had been measured also, after jarring, it would probably have been found to be nearer 2.9 to 1 than 1.9 to 1, and the calculated required thickness would have been correspondingly increased.

The influence of even a slight amount of vibration is well illustrated by the difference between the co-efficient of friction of stones on one another in motion and repose. Granite blocks, which will start on nothing flatter than 1.4 to 1, will continue in motion on an incline of 2.2. to 1, and, for similar reasons, earthwork will assume a flatter slope and exert a greater lateral pressure under vibration than when at rest. This fact has long received practical recognition from engineers; indeed, attention was called to it by Mr. Charles Hutton Gregory, C. M.G., Past-President Inst. C.E., in a Paper on slips in earthwork, read before the Institution in 1844, when the President and others gave instances of slips in railway cuttings caused by vibration;

The general results of the preceding and other independent experiments on retaining walls tending to throw a doubt on the accuracy of Lieutenant Hope's measurement of the direct lateral thrust of ballast and sand on a board 1 foot square, the author considered it advisable to repeat those experiments. Care was taken to eliminate all disturbing causes tending to vitiate the results. The pressure board was held by a string at its center of pressure, and was perfectly free to move in every direction, which, of course, a retaining wall having a greater hold on the ground than stability to resist overturning has not. In every instance the filling was poured into the box and allowed to assume its natural slope towards the pressure board, and the latter was rotated and thumped to keep the ballast alive before the reaction was measured. In order to avoid all chance of the bias which the knowledge what to expect might have given him, as it did Lieutenant Hope, the author had the experiments made by others who were ignorant even of the object of them, whilst he himself purposely experimented with an apparatus the dimensions of which he did not know, and consequently could form no estimate of the weight which would be required in the scale

With clean dry ballast having a natural slope of $1\frac{1}{3}$ to 1, it will be remembered Lieutenant Hope obtained a lateral pressure on 1 square foot of 9 lbs. 7 oz. With well-washed wet ballast of the same kind the author found the natural slope to be $1\frac{1}{2}$ to 1, and he decided therefore to use the ballast wet, because, possessing greater fluidity, it would give more uniform results than dry ballast, and also impose greater lateral pressure. In a large number of independent experiments the results were uniformly as follows (Ex. 19): With 6 lbs. in the scale the board moved forward about $\frac{1}{2}$ inch, but continued to retain the ballast; with 7 lbs. very slight movement occurred; with 8 lbs., no movement at all; and with 10 lbs., under extreme vibration, the board moved forward about as much as it did with 6 lbs. without vibration. The general opinion of the different experimentalists was, that the fair value of the lateral pressure of this wet ballast was 7 lbs., because when that weight was in the scale pad a slight jolt was sufficient to let the ballast down by the run to a slope of $1\frac{1}{2}$ to 1. The board being 1 foot square, this of course is equivalent to the pressure of a fluid weighing 14 lbs. per cubic foot, instead of the 19 lbs. obtained by Lieutenant Hope, and the 26 lbs. indicated by theory.

With the same ballast unwashed and mixed with slightly loamy pit sand (Ex. 20) the natural slope was 1 to 1, without vibration, and $1\frac{1}{4}$ to 1 with a moderate amount of vibration. A weight of 3 lbs. was as effective in retaining this ballast as 6 lbs. in the former instance; 4 lbs. held it under a moderate amount of vibration, but $3\frac{1}{2}$ lbs. failed to hold the board under very little. Practically speaking, the lateral thrust was about half that with the clean wet ballast, and considerably less than half that theoretically due to the slope of repose of the loamy ballast.

In harbor works both walls and backing are frequently completely immersed, and, so far as gravity is concerned, stone blocks and rubble become then transformed into coal. The author, therefore, experimented (Ex. 21) with some coal having a peculiarly "greasy" surface, and offering the advantage of exceptional fluidity. With 3 lbs. the board moved forward about 1 inch, but no more until a slight jar was applied, when it

fell; with 4 lbs. a moderate amount of vibration also generally caused failure; with 5 lbs. the board usually moved forward gradually without making a rush so long as a tolerably considerable amount of vibration was maintained. When a slip occurred the slope was invariably $1\frac{3}{4}$ to 1. The coal proved to be more sensitive to vibration than the wet ballast, and still more so than the unwashed ballast. A weight of 4 lbs. with the coal appeared to be equivalent to 7 lbs. with the washed and $3\frac{1}{2}$ lbs. with the unwashed ballast. The weight of the coal being one-half that of the wet ballast, and the respective slopes of repose being $1\frac{3}{4}$ and $1\frac{1}{2}$ to 1, the lateral thrusts would theoretically be as 16.8 : 28.7, which is practically the experimental result of 4 to 7.

The author having occasion to design a solid pier 42 feet in height from the bottom of the harbor to the surface of the quay, where a soft bottom of great thickness and small consistency precluded the use of concrete block or other retaining wall, adopted an arrangement in which an iron grid of rolled joist, with a backing of large blocks of rubble, was substituted for a wall. It was necessary, therefore, to know the lateral thrust of large blocks of stone in such a structure, and mistrusting theoretical deductions, the author made direct experiments on a model to a scale of 1 inch to the foot.

In this instance the individual stones were intended to be fairly uniform in size, and of lateral dimensions not less than $\frac{1}{20}$ of the height of the wall, so that the conditions differed considerably from those assumed in theoretical investigations. A number of billiard balls exactly superimposed in a tightly fitting box would exert no thrust though their slope of repose might be as flat as 3 to 1; and it is not quite clear how nearly or remotely large boulders in an iron cage approximate to that condition. The stones used in the experiment were waterworn pieces of schistose rock having a "greasy" surface and a slope of repose of $1\frac{1}{2}$ to 1. This inclination was found by the author to obtain in natural slopes of all heights, from the pile of metalling by the roadside to the hills themselves. He ascended one slope of $1\frac{1}{2}$ to 1, over 500 feet in height, and found the balance was so nearly maintained that a footstep at times would set many tons of stones in motion; and a few winters ago a couple of stones of the respective weights of 18 tons and 22 tons, descended this slope and acquired sufficient momentum to carry them across a road at the foot of the slope and on to the middle of the lawn in front of an adjoining shooting lodge.

The conditions of the material were thus favorable, as in the instance of the coal, for obtaining uniform results and a maximum lateral thrust. In order to exclude all possible influence from side friction, the length of the box was made four times the height of the wall. As the result of ten experiments (Ex. 22) it was found that a weight in the scale corresponding to the pressure of a fluid weighing 10.2 lbs. per cubic foot sufficed to retain the rubble, though the face planking moved forward slightly as the last few shovelfuls were thrown against it. The weight of the stone filling was 98 lbs. per cubic foot, or practically the same as that of the wet ballast last referred to; so the 10.2 lbs., or say under slight vibration 11 lbs., in the present instance compares with the 14 lbs. of the previous instance, and the difference is a measure of the influence of large-sized, smooth-faced boulders as compared with ordinary ballast.

With coal of the same size (Ex. 23) the equivalent weight of fluid was 6 lbs. per cubic foot, which confirms the preceding result when regard is had to the respective weights and slopes of repose of the two materials. The experiments collectively proved that a wall, which according to the ordinary theory would be on the point of being overturned by the thrust of a bank of big boulders, would in fact have a factor of safety of nearly $2\frac{1}{2}$ to 1.

REPORTS OF ENGINEERING SOCIETIES.

The Iron and Steel Institute.—The Autumn Meeting of the Iron and Steel Institute of Great Britain will be held in London on the 11th and three following days of October. An influential committee has been formed in London for the purpose of making arrangements for the reception and entertainment of the Institute. A programme of the proceedings will appear in due course.

American Society of Civil Engineers.—The last number of Transactions contains the address of President Francis, already published in this magazine; also minutes of

the June meetings of the Society and of the Board of Direction. In addition to the above are the following important reports:

Report of the Committee on the Engagement of Civil Engineers on Government Works.

Report of Committee on Uniform Method of Tests of Cement.

Report of Committee on Tests of Iron and Steel.

Report of Committee on Gauging of Streams.

A very important report upon experiments upon Thenix columns has been presented to the Society, and is in course of preparation.

ENGINEERING NOTES.

The Garabit Viaduct.—The Garabit viaduct, the construction of which has recently been commenced, is on the line of the Marvejols-Neussargues railway, crossing the valley of the Trueyre, at an elevation of 412 feet above low-water mark, where the valley is 1,800 feet wide. In M. Eiffel's design, a large arc, like that of the Douro viaduct, but a little larger, is employed. The height is limited to 262 feet (80 meters) of which there are 59 feet of masonry in the piers, as a base, and 203 feet in height of ironwork. The total length of the viaduct is 1,813 feet. Of this the iron portion is 1,470 feet in length; the remainder is of masonry. The ironwork consists of seven spans, including three on the Marvejols side, making a length of 887 feet; two on the Neussargues side, 341 feet long, and three supported by the central arch, together 242 feet.

The straight girders are of simple lattice work, consisting of St. Andrew's crosses, and are 17 feet high. The way is placed at a level of 5½ feet below the upper booms. The ironwork of the large piles next the arch is constructed in six stages, and is 200½ feet high, 49 feet by 23 feet at the base, tapering to the dimensions 16½ feet by 7 feet 8 inches at the top. The chord of the arch is 165 meters, or 541 feet, in length, with a rise of 60 meters, or 196¾ feet, and the depth at the crown is 10 meters, or 33 feet. It consists of two principal frames of latticework, 20½ feet apart at the middle of the arch, opening out to a width of 65½ feet at the ends, in order to give great stability to the arch for resisting high winds.

All the proportions have been calculated for a maximum stress, under the combined efforts of load and wind, of 6 kilogrammes per square millimeter, or 3.81 tons per square inch. The force of wind has been taken as 31 lbs. per square foot whilst the trains circulate, and as 55 lbs. per square foot without trains on the viaduct, when circulation would be impracticable. In comparing the influences respectively of the load and the wind on the co-efficients of stress, it is notable that, in general, the main portions of the arch are subjected to stress as follows:

2 kilogrammes	per square centimeter, or 1.27 ton per square inch, under the weight proper, or permanent load.		
2	"	"	under the surcharged loads.
2	"	"	under the force of wind.

The maximum variation of stress by variation of temperature takes place at the crown of the arch, being 0.40 per ton per square inch, for 30° Centigrade, or 54° Fahrenheit.

For the lattice portions of the arch the stress is, under the weight proper, 1 kilogramme or 0.625 ton; for the surchage it is the same; and for the wind only, 3 kilogrammes, or 1.9 ton.

The total weight of the ironwork will be about 3,200 tons, and the cost, including that of the masonry, will amount to £124,000, being at the rate of £68 per lineal foot.—*Abstracts of Inst. Civil Engineers.*

On the Past and Present Water Supplies of Calcutta.—Mr. Pedler, in a valuable paper, contrasts the existing and past supplies to this town, and by a series of tables shows the importance to health and life, especially in the East, of a pure water supply. The former supply to Calcutta was from tanks and wells in the city, whose natural impurities were increased by the heat of the climate, which, especially at certain seasons, would tend to develop the incipient germs of animal life, whilst aiding the production of chemical compounds. The present supply is pumped from the Hooghly at Pultah; it is there collected in settling tanks, and after subsidence it is filtered through sand and then supplied to Calcutta; and on analysis, although the water is not of "great organic purity," it is well within the class of "fair organic purity," according to Dr. Frankland's standard, and compares well with English town supplies. The tables in this paper show the effect of impure water on the general mortality of the town, especially with regard to cholera, typhoid fever, and other diseases. Professor Wanklyn's system of analysis was adopted, instead of the refined one of Dr. Frankland, which was considered to take too much time, although more perfect.

The quality of the supply on the old system is described by the author thus: "A good average quality of Calcutta, or shallow well water, may be made by mixing six parts of our hydrant water with from one to two parts of the most concentrated Calcutta sewage." In 1879, 7,464,159 gallons of filtered water were supplied daily, to a population of 429,535; that is, 17.4 gallons per head. The total supply, filtered and unfiltered, was 8,556,025 gallons, or 20 gallons per head per day; it is, however, proposed to double the supply of filtered water to 16,000,000 gallons, or 37.2 gallons per head per day. (The average supply in large towns in England is 25 gallons per head).

The seasons have a very strong effect on the quality of the water, the rainy season greatly increasing its purity; the melting of the snow on the Himalayan range helps in this direction, and the river is most pure in October.

The total solid impurities in October are 11.30 parts in every 100,000 parts of water, and in May 21.68.

It is proposed to take the supply of water from the Hooghly rather nearer Calcutta, but the author seems to be rightly against this, on account of the danger of increasing the impurity by the tidal water.—*Abstracts of Inst. of Civil Engineers.*

Jacquel's Tug System.—It has hitherto not been possible to use steamboats, whether paddle or screw, on canals of small section, for three reasons, viz., 1st. Because the waves generated by the propellers would destroy the sides of the canal; 2nd. The propellers themselves would be very liable to injury when passing through locks and other narrow places; and 3rd. Such boats cannot take a sufficiently large cargo in these canals to pay expenses.

In the steam tug system of Paul Jacquel of Natzweiler, Alsace, the screw is within the body of the ship, and surrounded by a cylinder or tunnel, and is fed with water by two large channels or passages leading from the sides of the boat to the front face of the screw. The advantages claimed for this arrangement are: 1st. That the screw is protected from injury: and, 2nd. That the stream of water thrown astern so concentrated in direction by the cylindrical casing that the banks are preserved from injury. 3rd. The boat being a tug, not herself carrying a cargo, and consequently drawing always the same depth of water, can transport a large train of barges, at from three to four times the speed of horses. 4th. These tugs can always depend on their rudders for steering power, and thus render the use of steering poles unnecessary. These poles being invariably used with ordinary canal boats, and being constantly driven from 3 to 5 feet into the banks of the canals, render the maintenance of the latter very expensive, and frequently cause dangerous infiltrations.

The author accompanied Herr Jacquel on the trial trip of his first tug on the Saar coal canal, which was so successful that he is now engaged in organizing a complete sytem of steam transport on this canal.—*Abstracts of Inst. of Civil Engineers.*

The Boring for the Panama Canal.—A brief account of the borings which have now been made for the Panama Canal has been communicated to the French Academy by M. de Lesseps; and they are of a nature to show that the work of excavation will be less arduous than was at first supposed. The preliminary surface bores, and the examination of boulders found along the route, had led the engineers to expect that the Culebra mountain, separating the maritime plains of the two oceans, was formed of a massive compact rock covered with a layer of vegetable humus only a few yards thick. But since the month of March last several deep bores have been made into the summit of this hill. Three of these begin at altitudes of about 100 feet above the level of the sea, and are already some 40 feet deep; but as yet no rocky strata have been encountered. The soil, in fact, is a conglomerate of clay mingled with globular fragments of dolomite varying in size from sand to pebbles. These curious balls of stone are paralleled by the resinous trachyte found in the islands of Ponza, between Terracina and Gaëta, in the Mediterranean. The balls are, strictly speaking, ellipsoidal, and crumble on exposure to the air, splitting up at the same time into concentric shells with a hard kernel inside. The boulders scattered along the track are of the same formation, and the many colored clays cut through are evidently due to the decomposed balls. In short, the rocks of this part of the isthmus appear to be all clayey breccias and conglomerates, which will give a stable slope to the great cuttings without seriously impeding its excavation.

The Mont Blanc and Simplon Tunnels. According to the Paris correspondent of the *Gazzetta Piemontese*, the supporters of the rival tunnels are actively at work, but the prospects of the Mont Blanc scheme are the brighter. The Commission selected by the French Chamber of Deputies to consider the matter, has returned from inspecting the places concerned; and it is believed that their impressions were favorable to the Mont Blanc. According to the surveys of MM. Lepinay and Garola, the line can be carried from Bonneville to the northern entrance of the tunnel, and from Torea to the southern entrance, without exceeding a gradient of 12.50 in 1000, and that without serious difficulty. At the Simplon, on the other hand, new surveys are being made in hopes of reducing the gradients to 13 in 1000; but, in order to do so, it will be necessary to erect a viaduct 200 meters high over the Diveria, and to perform other lesser engineering works. In order to connect the tunnel with the Jura railways a branch line would have to be constructed, which would have three tunnels (one of them 8 kilos. long), and would cost 100 million francs. For the same sum, not only the lines of access to the Mont Blanc, but the whole tunnel as well, could be executed. The report of the Commission is being prepared by M. Sesguiller, and he promises that it shall be presented to the Chamber during the present session. If the decision is favorable to the Mont Blanc, negotiations will be immediately commenced with Italy, in order to agree on the division of the expense. It is said that the majority of the Commission are in favor of asking Italy to undertake the construction of the southern lines of access, while France bears all the expense of the tunnel itself. The correspondent learns that an English company designs to tender for both the Channel Tunnel and that of the Mont Blanc, with all its lines of access. An international company is talked of to construct and work the whole line from Dijon through to Broni.

Continuous Brakes.—Earl de la Warr, in the House of Lords, recently, called attention to the subject of continuous brakes. His lordship dealt at some length with the unsatisfactory state of things revealed by the return for the half-year ending December, 1880, pointing out that upon the whole there were only about seven companies out of 90 in the United Kingdom who were actively carrying out the recommendations of the Board of Trade, and that the number of carriage stock so fitted with continuous brakes amounted only to 11 per cent. of the total carriage stock of the country. Under these circumstances did the Government propose to take any steps to enforce the regulations of the Board of Trade? Lord

Sudley, in replying, seemed desirous of covering the supineness of the railway companies by stating that 17,654 carriages, or 41 per cent. of the whole stock, were fitted with continuous brakes. A glance at the returns, however, shows this to be a complete mistake, for nearly half this number are not continuous but sectional brakes, chiefly in use on the London and North-Western and Lancanshire and Yorkshire railways. The remainder are certainly continuous, but not much more than one-half of them are automatic, and those which are, form, as Earl de le Warr correctly stated, only 11 per cent. of the whole carriage stock of the country. Again, we are informed that the Board of Trade have been in communication with the London and North-Western Railway Company, and it was hoped that by the pressure of public opinion and the efforts of the Board, the end which the noble lord had in view would be brought about without legislation. Lord Colville, in supporting the action of the Great Northern Railway Company, of which he is chairman, congratulated himself on the fact that his company had fitted so many vehicles with Smith's vacuum brake, and made the remarkable statement that the Midland Railway and the London and North Western Railways were also applying the Smith's vacuum brake to their stock. His lordship was, no doubt, unaware that this was not the fact. On one point, however, he had been better informed, for he went on to say that it was generally believed "that if you made the Smith's vacuum brake automatic, you spoiled it." Our opinion of automatic vacuum brakes is much the same as that of his lordship.

IRON AND STEEL NOTES.

Improvements in the Basic Bessemer Process.—Steelmaking from phosphoriferous pig iron seems to made rapid strides on the Continent, for we hear that new Bessemer works are under construction at Ars on the Moselle, in Lorraine, and at Volklingen, near Saarbrucken, both of which are intended to make steel from the cheap "minette" iron ore, a description of ore resembling much the Cleveland oolitic ironstone, and which is found in enormous deposits in Luxemburg and Lorraine. When the basic process with a converter lining of dolomitic bricks was first introduced, the Rheinische Stahlwerke at Ruhrort, and the Horder Berg-und Huttenverein were not slow in appreciating its value, and to secure the patent rights for the German empire. Though the validity of the patents was energetically contested by a combination of German ironmasters, the patentees succeeded, nevertheless, to override all opposition in the various law courts where the matter was to be decided. The first step was the introduction of basic bricks for converter linings instead of the usual ganister or fire-brick lining, the second that of the addition of basic fluxes in combination with a prolonged afterblow, after the elimination of silicon, carbon, and manganese from the metallic bath. It was then considered essential that the basic cinder should contain from 36 to 40 per cent. of lime and magnesia, and only from 8 to 20 per cent of silica, and that the fluxes added to the metal should be, firstly, a mixture of about 9 parts lime and magnesia, with 1 part red oxide of iron; and secondly, after a blow of 6 to 10 minutes a mixture of 2-3 parts of lime with 1 part of oxide of iron, such as red hematite. The admixture of oxide of iron proved the more necessary the less the quantity of manganese was in the pig iron, and whenever the same was very large it could be left out altogether.

It is now well understood that the phosphide of iron only begins to be decomposed after all silicon and carbon is gone, that is after the characteristic carbon lines have completely disappeared in the spectroscope, and that its decomposition requires afterblowing of several minutes, when only the oxidized phosphorus will combine with the bases of the flux, chiefly with its lime and oxide of iron, which combination is accompanied by a voluminous emission of brown smoke, caused by burning iron. After the removal of the phosphoriferous cinder, spiegeleisen was then added, in order to reduce any oxide of iron which was dissolved in the fluid metal, and besides to dose it with sufficient carbon for becoming ingot iron, mild steel or hard steel, as required. This mode of procedure was the usual one with the grey phosphoriferous pig iron; the afterblow has, however, some inconveniences, which consist in the loss of metal and the greater amount of time. The Rheinische Stahlwerke have therefore tried to replace the afterblow by another oxidizing reaction, and to employ combined oxygen instead of free atmospheric oxygen for the elimination of phosphorus. The bearers of combined oxygen are the oxides of iron and manganese, which are introduced either in the solid or in the molten state, and intimately mixed with the metallic bath. The quantity of oxides is determined from that of phosphorus, and their oxygen ought to contain as much as 25 per cent. more than the free atmospheric oxygen, which would have to be blown in the metal, if it were to be finished by the usual afterblow.

The basic process has been in successful operation at Ruhrort since September 22, 1879, as well as at Horde. Licenses to use the patents, which were partly acquired from Mr. S. G. Thomas, partly taken out independently, have been granted in Germany and Luxemburg to the following iron and steel works, viz.: Gebruder Stumm of Neunkirchen, the Dillingen Iron Works near Saarbrucken, Gebruder Gienanth of Kaiserslautern, Messrs. Les Petits fils de Fois de Wendel & Co. of Hayange, Messrs. de Dietrich & Co. of Niederbronn, the Burbach Iron Company, the Rothe Erde Iron Works of Aachen, the Lothringen Iron Works of Ars-on-the-Moselle, the Maximilianshutte of Regensburg, and the Bochum Steel Works. It appears that, besides the Bessemer converter, the dephosphorising process makes favorable progress in the open-hearth furnaces as well, when basic flukes, such as lime, dolomite, oxides of iron and manganese are employed. Among their number reappears the fluoride of lime, fluor spar or "cand" of the

Cornish miners, which was patented some fifteen years ago by the late Professor Theodor Sheerer, of the Bergakademic of Freiberg, Saxony, for the purpose of dephosphorizing iron in the puddling furnace. When fluoride of lime was tried at the Horde Works, at the instance of Professor Sheerer, it was found that other combinations of lime, when in a fluid state, would react upon the phosphorus as well; for instance, chloride of lime and also chloride of magnesia, though they are more liable to be decomposed into chlorine and lime or magnesia by heat alone, while for the decomposition of fluoride of lime the presence of silica is essential. All these fluxes will, of course, act as well in the Bessemer converter; and as fluoride and chloride of lime form a very thin and fluid cinder, they seem to be far better suited for the washing out of phosphorus out of the metallic bath, than caustic lime or magnesia, or a mixture of both, which do not melt, and therefore come very much less in contact with the particles of phosphide of iron which are to be decomposed, than a more fluid substance.

RAILWAY NOTES.

The St. Gotthard Railway.—This railway is now so rapidly approaching completion that a table of the fares to be charged on it are already printed. Starting from Rotkreutzi 11 miles from Lucerne, the St. Gotthard line runs along the western shore of the Lake Zug, round the base of the Righi and by Lake Lowerz, striking the Lake of Lucerne at Brunnen. From Fluelen the line begins to ascend the valley of the Reuss, attaining an altitude of 1558 feet above the level of the sea at the village of Erstfeld, five miles from Fluelen. Up to this point the gradient of the line nowhere exceeds 10 in 1000; but from Erstfeld to the next station, Amsteg, it rises 26 feet in every 1000. From Amsteg the line runs through a number of short tunnels and over a number of bridges to Gurtnellen, eight miles from Fluelen, where it attains an altitude of 2427 feet. From Gurtnellen, the line ascends the mountain side in a series of bold spirals, crossing the Reuss several times, and passing through the Pfaffensprung tunnel, 1487 meters in length. And then, running through the Wattingen tunnel, reaches the station of Wasen, 3008 feet above the sea level. Leaving Wasen the line runs back again in the direction of Fluelen; then, turning, passes through the Naxberg tunnel, 1570 meters in length, and reaches the station of Goschenen. Here the St. Gotthard tunnel, nine and a-half miles long, begins.

Ventilation of the the Mont Cenis Tunnel.—A recent report by Signor Frescot, one of the engineers of the railways of Upper Italy, gives some interesting facts with regard to vetilation in the Mont Cenis Tunnel—facts which may be useful for the solution of the same problem in the St. Gotthard. The Mont Cenis Tunnel is 12,500 meters in length, and has a capacity or 500,000 cubic meters. The mean temperature is 25° C. In winter this causes sufficient natural ventilation, aided by the difference of altitude of the two extremities (132.5 meters). But in summer the external and internal temperatures are often equal, and artificial means of ventilation have to be adopted. It is a question, as will at once be seen, of considerable importance. The passage of twelve trains in the day may be assumed containing 2500 passengers, each passage through the tunnel occupying half an hour. The locomotives burn anthracite, which produces less carbonic oxide than coke, and the combustion is rendered as complete as possible. Now, it is estimated that the average total production of carbonic acid in the tunnel per day is 6987 cubic meters, of which 6930 cubic meters are attributed to the trains, the rest to employes, passengers, and lights. The normal proportion of carbonic acid in the atmosphere varies from 0.0C03 to 0.0005. People can live in an atmosphere containing as much as 0.005. It has been proposed to attain in the Mont Cenis the same degree of purity as in our Metropolitan Railway, or 0 0015 of carbonic acid. With this view, a large centrifugal ventilator has been set up on the Bardoneche side; it is driven by water, which is abundant there. The entrance of the tunnel is closed by a door, which the trains open on passing under the arch, and close after passing. In winter, and also during some fresh nights in summer, the machine can be stopped, and any necessary repairs made. In addition to the ventilator, there is in use the compressing and aspirating apparatus that was employed in making the tunnel. Notwithstanding these means and care bestowed on the fires of the locomotives, there is reason to fear that the present ventilation would prove insufficient in case of even a small increase of the traffic.

ORDNANCE AND NAVAL.

Austrian Torpedo Boats.—The official trial of the first of two sea-going boats built for the Austrian Government by Messrs. Yarrow & Co., of Poplar, was carried out last month, when the speed realized was considerably in excess of that stipulated for in the contract. The boat is one of several now in course of construction for various governments, by Messrs. Yarrow; she is of the "Batoum" type, but is in many respects an improvement upon that vessel, which was built last year by the same firm for the Russian Government. The present vessel, which is steel built throughout, is 100 feet long by 12 feet 6 inches beam and 6 feet 6 inches deep, which gives a thorough sea-going craft, and one capable of stowing sufficient fuel for a run of from 800 to 1,000 miles at a ten-knot speed. She is fitted with a pair of compound overhead cylinder engines, the high-pressure cylinder being 12½ inches and the low-pressure 21¼ inches in diameter, with a 16-inch stroke. Her boiler is of the locomotive type, having 922 square feet of heating surface, and being placed forward with the engines aft. She is propelled by a single screw, 5 feet diameter and 6 feet 6 inches pitch. She

has a closed stokehole, with a fan drawing the air supply from the engine room, into which air is admitted by four small siphon inlets on deck in place of one large ventilator as formerly used, which is one of the improvements introduced by Messrs. Yarrow. Another and, in fact, the principal new feature, is, that the torpedo tubes—there being two for two Whitehead torpedoes—are completely encased within the bows instead of projecting from it, as formerly, and provision is made for a man to go down and obtain access to the front end of the tubes if necessary. The boat is fitted with bow and stern rudders, and is steered from a conning tower placed forward, steam steering gear being provided. This, coupled with the bow rudder, which is balanced, adds very considerably to the rapidity with which she can be manœuvred. The officers' quarters are placed aft and those of the crew forward. Another feature is the provision of means for working the engines at high pressure if the condensers get damaged in action. Should she spring a leak ample pumping power is provided, there being a 2-inch hand pump, a 3-inch steam pump and the 4-inch circulating pump of the engines available. The trial was made with twenty persons on board and 2½ tons of coal in her bunkers, which is sufficient to carry her over a 300 mile run. Her engines are of 550 horsepower indicated, and this was obtained on the trial with a pressure of 112 lbs. per square inch and 440 revolutions per minute. The speed attained was 22.1 knots, being 1.6 knot above the speed stipulated for in the contract, which is 20.5 knots. Altogether the results were highly successful, and the Austrian Government officials expressed their satisfaction with the performance of the boat.

A New Submarine Vessel.—A young Roumanian engineer, Trajan Theodoresco, has succeeded in constructing a submarine vessel which puts everything that has gone before in submarine navigation completely in the shade. This boat, up to a certain maximum size and corresponding tonnage, it is said, may be navigated under water for twelve hours at a stretch, at a depth of 100 feet; she may, however, according to the inventor, be lowered to over 300 feet below the surface of the water, and without coming into contact with the atmosphere. On the surface of the water the vessel may be manœuvred under the same conditions as an ordinary steamboat. Her speed, however, is not so great as that of steamers, but greater than that of sailing vessels. The submersion is effected by screws and vertically, either suddenly or successively, and the vessel is raised in the same way. If once under water, sufficient light is supplied enabling those on board to see all obstacles at all distances up to 130 feet, and the movements of the boat may be so regulated as to avoid them. The air supplied for the crew is said to last for from twelve to fourteen hours. In case of need, the reservoir containing the air may be refilled, while under water, for another twelve hours, pipes telescoping into each other being directed to the surface for that purpose. The propulsion of the vessel and its submersion are stated to cause no noise. Should all these particulars prove correct, the novel boat will be the most formidable vessel for torpedo warfare. But she may also be turned to more useful purposes. In the Matchin Canal, near Braila, there lies, since May, 1877, the "Lutfi Djelit," which had on board the war-chest of the Turkish Danube flotilla, amounting, so report says, to several million piasters. It might be possible to recover that sum by means of the new submarine boat, and if the experiment should prove successful, it would at the same time be profitable.

New Gun Vessels for China.—An important addition has just been made to the fleet of gun vessels with which the Chinese navy has been supplied by Sir W. G. Armstrong & Co. during the last few years. Already eleven vessels have been sent out from time to time, differing in details, but uniting the peculiarity of extraordinary gun power in diminutive craft. The two new vessels differ essentially from the preceding eleven in combining great speed with great gun power. They resemble the others, however, in being wholly unarmored. Their displacement is 1350 tons. They are built of steel, and are propelled by twin screws driven by compound engines of, together, 2600 indicated horsepower. They each carry two 26-ton 10-inch breech-loading guns mounted upon center pivots, one forward and one aft. Each of these heavy guns commands a nearly all-round fire. The charge of the gun is 180 lbs. of powder, and the weight of projectile 400 lbs., the penetrative powder equal to piercing 18 inches of solid, unbacked iron plate. They carry, besides, in each, four 40-pounder breech-loading guns, two 9-pounder breech-loading guns, two Nordenfelts, and four Gatlings, and, furthermore, two steam cutters fitted with spar torpedoes. The engines, boilers, magazines, and machinery are entirely below the water line. and are further protected by a steel-plate under-water deck, the space between which and the main deck is divided into numerous watertight compartments, in which coal is stored, thus adding to the protection afforded by the deck. Hydraulic steering gear is provided and placed below the water line, with alternative hand gear and tiller. The vessels are also armed with a formidable steel knife-edged spur, or ram. The coal bunkers take 300 tons of coal, and with that quantity the vessels can run continuously at a speed of about eight knots for weeks together. On the 14th and 15th inst. the new vessels went through a complete course of trials off the mouth of the Tyne, under Admiralty inspection. Their speed was tested over a course of 10¾ knots, and was shown to be, with all weights on board, on the average of two runs each, over 16 knots in one vessel and 16 knots in the other. The guns were fired with battering charges abeam, ahead, and astern, and at different elevation up to the maximum. Not the slightest sign of weakness was exhibited in any part of their structure. The handiness or power of manœuvring was found remarkable. With engines stopped suddenly, they were

brought up in about 3½ lengths. Reversing the engines brought them up in about 1½ lengths. With one engine driving ahead and other astern, they circled rapidly to port or to starboard in their own length. With the hydraulic gear, the rudder was put over from hard-a-port to hard-a-starboard in eight seconds. The vessels were kept easily circling round a drifting target at about 150 yards, while the target was being riddled by the machine guns. Without claiming too much for these vessels, it should be remarked of them that the penetrative power and range of their guns measured by the accepted official standard, exceed those of any gun yet afloat, except those of the English "Inflexible," and the Italian "Duilio. No unarmored ship that carries guns can be compared for a moment with them, and no armored ship equals them in speed. The nearest is the "Duilio," of nine times their size. Thus their vastly superior gun power would make them most formidable to the largest unarmored vessels, and their superior speed and greater range and power of artillery would enable them to in some measure cope with an ironclad, since they could ordinarily choose their own distance, and from their diminutiveness would be very hard to hit; nor would a single shot by any means disable them, owing to the under-water and other protection given to their vital parts. As skirmishers to open attack, or as cavalry to harass a retreat, they would prove valuable adjuncts to a first class navy, and they are not subject to the rapid depreciation which the progress of artillery imposes upon a costly and necessarily limited ironclad fleet. The vessels are being commissioned by Admiral Ting with officers and crews sent from China, and Admiral Ting will shortly call in at Portsmouth for the purpose of paying his respects and showing his vessels.

BOOK NOTICES.

Publications Received.

Through the kindness of Mr. James Forrest, Secretary of the Institution of Civil Engineers, we have received the following papers of the Institution.

The Flow of the River Thames. By John Taylor, M.I.C.E.

The Protective Works for Preventing the Threatened Outbreak of the South Rangitata River, N. Z. By John Henry Lowe, M.I.C.E.

Portland Cement Compo and Concrete at Garvel Dock Works, Greenock. By Walter Robert Kinipple, M.I.C.E.

Dredging on the Lower Danube. By Charles Henry Leopold Kühl, M.I.C.E.

Explosions of Fire Damp. By Prof. Haton de la Goupilliere.

The Use of Cellular Caissons. By Charles Andrews, M.I.C.E,

The Empress Bridge over the Sutlej. By James Richard Bell, M.I.C.E.

The Paroy Reservoir. By William Bell Dawson, A.M.I.C.E.

Scarborough Harbor Improvement. By John Hawkins, M.I.C.E.

Friction of Timber Piles in Clay. By Arthur Cameron Hurtzig, A.M.I.C.E.

The Osakayama Tunnel. By Thomas Munson Rymer-Jones, M.I.C.E.

Annual Report of the Astronomer in Charge of the Horological and Thermometric Bureaus of the Winchester Observatory of Yale College. New Haven: Tuttle, Morehouse & Taylor.

Monthly Weather Review for July. Washington: Government Printing Office.

A Manual for Managers, Designers and Weavers of Textile Fabrics. By Alfred Spitzli. West Troy: A. & A. F. Spitzli.

This is in the fullest sense a technical work, but it is designed to be of great value to all interested in the manufacture of textile fabrics. Arranged on the plan of a dictionary of technical terms, it is occasionally expanded to include the explanation of a process, or the description of a machine and its working.

It includes also, rules, tables and elementary instruction for beginners.

A Manual of Sugar Analysis. By J. H. Tucker, Ph. D. New York: D. Van Nostrand. Price $3.50.

The question of sugar adulteration has quickened the interest in all methods of detecting fraud. There has been of late a brisk demand for good guides to analysis of sugars.

The book before us seems to fill the requirements of the Chemist, who wants a complete manual for this branch of analytical work.

The scope of the treatise, which fills a royal octavo of 350 pages, may be inferred from the list of topics treated by chapters.

Chap. I. The Chemistry of Sugars as a class.
II. Cane Sugar, or Saccharose.
III. Dextrose and Levulose and Invert Sugar.
IV. Lactose or Milk Sugar.
V. Determination of Specific Gravity.
VI. Determination of Cane Sugar, Optical Method.
VII. Determination of Cane Sugar: Chemical Method.
VIII. Determination of Dextrose and Invert Sugar.
IX. Analysis of Raw Sugar.
X. " Molasses and Syrups.
XI. " Cane and Cane Juice.
XII. " the Beet and Beet Juice.
XIII. " Waste Products.
XIV. " Starch Sugar.
XV. Estimation of Milk Sugar.
XVI. Estimation of Dextrose in Urine.
XVII. Chemistry of Animal Charcoal.
XVIII. Analysis of Animal Charcoal.
Appendix.

A Handbook of Electrical Testing. By H. R. Kempe, M.S.T.E., &c. New Edition. Revised and enlarged. E. & F. N. Spon. 1881.

It is impossible to give a correct idea of the value of this work. There is none other with which it can be compared. Rivals it has no. any. True we have books that treat of testing

We have indeed small works, such as that of Hoskier, devoted entirely to testing, but in most cases testing is discussed in one or two chapters in books which deal with electrical matters generally. Mr. Kempe, however, has made testing *the* subject of his book, and any other subject that is discussed is discussed solely because of its connection with the principal subject. Now, a fair knowledge of testing is as necessary to the electrical engineer as a knowledge of certain branches of applied mathematics is to the engineer who undertakes the designing of bridges or similar constructions. Testing is a system of measurement, and implies a knowledge of the tools used as well as a knowledge of the properties of the materials employed. The tools used by electricians in their measurements are instruments of great delicacy and precision, and have a scientific as well as a practical value. The work before us describes these instruments, clearly showing the principle upon which the instruments is based, and the best methods of using it. It is with a certain amount of hesitation that we venture to hint at a seeming deficiency. The recent astonishing development of electric light apparatus opens a new field for testing operations, and we should have liked to have seen a chapter devoted to this special branch of the subject. Of course, it may be answered that the expert in testing can without the slightest difficulty apply his knowledge, inasmuch as no new principles are involved, and only care to be taken that his instruments are suited to large currents.

This work deals with testing from the standpoint of a telegraphist and has in view a thorough description of the tests requisite during the manufacture, laying, and repairing of as ubmarine cable. The value of the work arises not only from its comprehensiveness, but more from the excellent method pursued by the author. He not only supplies tests as devised for special purposes, and duly gives credit to the originator, but he discusses fully and freely the best conditions for making the test. The author is fully imbued with the idea that no effort should be spared to make the reader understand the "Why and the wherefore," and therefore he almost always illustrates his description by a numerical example. Thus to enable our readers to judge more easily our meaning, we indicate the method pursued in the discussion of Poggendorf's method of obtaining the E. M. F. of batteries. The method is in the first place described with the aid of a diagram, then a numerical example of the method is given, followed by remarks on the best conditions for making the test, and concluding the special subject by considering the possible degree of accuracy attainable. The method adopted by an author may be admirable, while his matter may be involved and difficult to understand. In this case the matter and method are equal, the former being clear, concise, and to the point.

MISCELLANEOUS.

STANDARD DANIELL CELLS.—At a recent meeting of the Physical Society Dr. James Moser exhibited a novel form of Daniell cell of the gravity type, intended as a standard of electromotive force. It consisted of a long glass vessel of tubular form, having a copper plate at the bottom immersed in sulphate of copper, and a zinc plate at the top immersed in sulphate of zinc. The two solutions are of course separated by their densities, but, as is well known, the copper solution tends to diffuse upwards into the zinc solution and deposit pure copper on the zinc plate. This diffusion is accelerated, too, by impurities falling from the oxidized zinc plate stirring up the solution below. Dr. Moser, however, prevents the sulphate of copper rising above a well-marked line of demarcation by simply suspending a small plate of scrap zinc by a string vertically into the liquid, so that the upward diffusion of the copper sulphate is arrested at the bottom of the suspended plate and copper is deposited on the latter. This cell is, however, not intended for yielding a constant current, and Professor Macleod, of the Indian Engineering College, Cooper's Hill, described a gravity Daniell devised by him for driving an electric clock. In this cell the two solutions are kept apart by surrounding the zinc plate with a cage of copper wire connected to the copper plate in the bottom of the cell. The trespassing copper solution is arrested by the cage, and copper is deposited on the wires, especially those on the upper sides of the cage immediately encircling the zinc. Dr. O. J. Lodge pointed out that this arrangement would not yield a correct standard of electromotive force, because all the copper plate was not wholly immersed in its own solution; it being a condition of accuracy that the zinc plate should be entirely immersed in the sulphate of zinc, while the copper plate is wholly covered by the sulphate of copper. Dr. Lodge is himself the inventor of a standard Daniell, which, we believe, gives very good results. In this, the copper plate and solution are contained in a glass test tube dipped into the sulphate of zinc solution; and the zinc plate is contained in a glass tube open at both ends and likewise immersed in the sulphate of zinc solution. In order to reach the zinc plate, the sulphate of copper has to diffuse out of the test tube, pass down the cell to the bottom, then rise up through the solution in the open tube. This is a process requiring considerable time, and it may be further checked by laying a piece of scrap zinc on the bottom of the cell.

A CORRESPONDENT of the *Times* writing from Shanghai in April last says "that the necessity for the preparation for a defensive war recently, woke China up very considerably. The telegraphs and the railways, and other modern productions of barbarian ingenuity, China has been forced to admit, are things that must be had even in a far eastern country, which has Russia for its most powerful enemy. Thus, it has come about that there is now more hope than ever that railway work and telegraph work will soon be common in China, and already a good deal of telegraph work is being carried out. A proposal to connect the capital with the Tientsin and the

Yangtsze by rail has been laid before the Throne by a most trusted general, and having been referred to the Governors-General of Chihli and at Nankin, it has been indorsed with their warm approval. But I hardly think the finances of China will permit her to embark on a scheme so extensive as this. All the money she can now scrape together from her impoverished exchequers or borrow from local banks will be required for the payment of the Russian indemnity. However, a railway from Pekin to Tientsin would not be so very costly, and it is now quite probable that the Chinese will be allowed by their paternal Government to set about making it at once. With the fear of invasion the desire for railways may pass away or grow weaker, but the events of the past few months have demonstrated to Chinamen the powerlessness of a country to avail itself of its resources for defence in an emergency, and the pride of the heads of the Government has been sufficiently wounded by proved incompetence, so that they will now exert themselves as strongly for improved inland communication as they formerly did against it.

The Dynamo Machine and Rolling Stock. The electric locomotive of Dr. Siemens will doubtless be useful in many ways, and prove a good auxiliary to the steam locomotive, but it will be very long, if ever, before it supersedes the latter for general traffic. There is, however, some value in the suggestion of Lieutenant Cardew to use the dynamo-electric machine in conjunction with the steam locomotive in order to communicate the power of the latter to the wheels of the carriages in a train, without having to resort to the wasteful "grip" or friction of the driving wheels upon the rails. Moreover, it could be made to apply the brakes to the carriage wheels in stopping the trains. Lieutenant Cardew's plan is to have a dynamo machine on the locomotive and each carriage, the revolving armatures being mounted on the axles of the wheels, and all connected up together in such a manner that the current generated in the armature of the locomotive machine by the revolution of its driving wheel would circulate through the magnets of all the other machines, turning round their armatures, and consequently also the carriage wheels. When it was desired to stop the train, the engine driver and guard, by means of two switches under their respective control, would change the direction of the current and reverse the motion of the armatures on the axles of the wheels, thus tending to bring the latter to a stop. The check would be strongest at first, and gradually die away; but this is in accordance with Captain Galton's finding that a brake should apply a powerful force to begin with for a short time, followed by a gradually diminishing one, in order to prevent the skidding of the wheels, which takes place if a strong pressure is kept upon them while they slacken. At first sight it might seem against Lieutenant Cardew's plan that the wire connections to be made would prove very inconvenient in practice where trains are made up of different carriages; but this drawback could be overcome by properly designated contact pieces. With regard to the efficiency of the dynamo-electric machine for transmitting power, M. Mascart has shown it to be a half when it is giving out work most *rapidly*, and Professor Ayrton has proved it to be as much as three-fourths when giving out work most *economically*.

Electric Lighting in Coal Mines.—The Royal Commissioners upon Accidents in Mines recently witnessed some very interesting experiments on the application of electric lighting to coal mines. The colliery selected for these experiments was the Pleasley Coliery, near Mansfield. The pits are about 1600 feet deep, and the workings are very extensive, but in the present instance the light was applied to three workings only, situated at a distance of about one third of a mile from the bottom of the pits. As it is a necessity in such an application of the electric light that the light itself should be absolutely cut off from all communication with the air surrounding the lamp, and also in order to permit of the use of a large number of separate lamps upon one circuit, the Swan system was employed. As our readers are aware, in this system the light proceeds from the incandescence of a fine fiber of carbon, the combustion of which is prevented by its being enclosed in an exhausted glass bulb. The light of such lamp varies from twelve to fifty candles, and as many as seventy lamps can be worked upon one circuit with an ordinary dynamo electric machine. The main wires were taken down the upcast shaft and connected at the bottom of the pit with cables, which were carried through the air passages till they arrived at the main levels. They were then taken along these main levels, and from them branch cables were carried up gates or side passages to the face of the actual workings. Here they were continued by insulated wires upon which the lamps were placed, and which were of sufficient length to reach to the extreme limits of the face of the coal that was being worked. The lamps themselves were enclosed in lanterns of a very ingenious construction, designed and made by Messrs. R. E. Crompton & Co., which enabled the very fragile glass bulbs to be carried about without fear of accident, and at the same time rendered it impossible that the fracture of the lamp within could cause an explosion, inasmuch as the air inside the lantern would suffice for the instantaneous combustion of the carbon filaments before the flame could be communicated to the external air. As in working the coal the men undercut the surface to the depth of 5 or 6 feet, and the superincumbent mass is then brought down by wedges or blasting. The new lamp was found to be admirably suited for the requirements of the workers, since it not only gave a light many times as intense as the lights it replaced, but it was equally brilliant in whatever position it was placed, and it required absolutely no attention. In addition to the lamps which were used in the actual workings of the pit, the pit bottom was lighted up with similar lamps. The number of lights employed in all was ninety-four, which were worked by the

current of an ordinary Gramme machine, driven by a portable engine, placed near the top of the upcast shaft. Had it been necessary, the number of lamps might have been considerably larger, but it was not desired to increase the scale of the experiment, as it was sufficient to test the practicability of the scheme. The whole of the arrangements were carried out under the personal superintendence of Mr. Harold Thompson, of the firm of R. E. Crompton & Co.. The Commissioners, including Mr Warrington Smyth, Professor Tyndall, Professor Abel, and others, spent two days in examining and testing in various ways the success of the experiment, and are reported to have expressed themselves as highly satisfied with the results obtained. It seems probable that this attempt will lead to further and more extensive experiments of a simlar kind.

The Faure Battery.—We believe that quite a number of installations for lighting purposes have already been made in private houses, so that the full practical value of the apparatus will not long remain an unknown quantity. Meanwhile arrangements on a large scale are being made in London for the practical and commercial development of the invention. We have already taken pains to criticize the unwise and exaggerated claims made for the Faure battery in Paris with which the financial combination that had acquired the patents thought fit to take the public by storm, and pointed out that an interesting and valuable invention was likely to suffer from such a treatment. We are therefore the more gratified to learn that, in this country at all events, the value of the Faure battery is not likely to be damaged in the same manner, the names of those gentlemen (especially that of Sir William Thomson) interested in the matter being a sufficient guarantee that no more will be claimed for the battery than it can fulfill. So far as light-producing is concerned, Sir William Thomson probably suggested the real field for its usefulness, and an enormous field it should be, when he said that the battery would do for the electric light what a water cistern does for an inconstant house supply. It will also afford the means of obviating those interruptions in an electric light arising from irregularities in the motor, or from its temporary disablement, since if the dynamo-electric machine be employed to charge the batteries, and the latter are used to supply the light, the resulting current will be absolutely uniform. For working tramways and for some other purposes the batteries have been experimented upon with reasonable success, and doubtless much will be done with them in this direction. All this, however, is widely different from the original and sensational proposition to deliver batteries daily from house to house for giving light and power at prices competing with gas and steam; widely different, and infinitely more satisfactory, and within its legitimate limits, we may expect to see the Faure battery take a prominent place amongst the practically useful inventions of the day. Before dismissing the subject for the moment, we wish to correct two errors which have unfortunately appeared in a recent note. The first referred to the date of the Faure patent, and stated that inasmuch as the date of this patent was the 26th of May, and that detailed descriptions of the arrangement had appeared in the public journals before that date, the validity of the patent may be called in question. So far from this being the case, the date of the patent protecting the Faure battery is dated January 11, 1881, long before any descriptions were made public, and subsequently patents have been granted in most other countries, including Germany and the United States, where objections are most easily raised and successfully contested. The patent dated May 26, to which reference was made, is, we believe, for further modifications not yet made public. The second error referred to the mode of charging the Faure battery. It was stated that it could only be charged by a voltaic battery. Were this the case the arrangement would of course be utterly without commercial value. As a matter of fact it can be charged by any direct current generator —*Engineering.*

Forth Bridge Railway.—The Forth Bridge Railway scheme, which provides for a bridge over the Firth of Forth, together with approaches on each side, is likely to be proceeded with, it having been arranged by the various companies concerned—namely, the North British, Midland, North Eastern, and Great Northern—to modify the arrangements embodied in the former bill, so that the Forth Bridge Company may be able to complete the undertaking; and it is expected that improvements will be made in the route to the North, in addition to those which will be secured by the construction of the bridge itself.

The Speed of Thought.—Helmholtz showed that a wave of thought would require about a minute to traverse a mile of nerve, and Hirsch found that a touch on the face was recognised by the brain, and responded to by a manual signal, in the seventh of a second. He also found that the speed of sense differed for different organs, the sense of hearing being responded to in a sixth of a second; while that of sight required only one-fifth of a second to be felt and signaled. In all these cases the distance traversed was about the same, so the inference is that images travel more slowly than sounds or touch. It still remained, however, to show the portion of this interval taken up by the action of the brain. Professor Donders, by very delicate apparatus, has demonstrated this to be about seventy-five-thousandths of a second. Of the whole interval forty thousandths are occupied in the simple act of recognition, and thirty five thousandths for the act of willing a response. When two irritants were caused to operate on the same sense, one twenty-fifth of a second was required for the person to recognize which was the first; but a slightly longer interval was required to determine the priority in the case of the other senses. These results were obtained from a middle-aged man, but in youths the mental operations are somewhat quicker than in the adult. The average of many experiments proved that a simple thought occupies one-fortieth of a second.

Authorities differ on the physical properties of ammonia, but so far as liquid ammonia is concerned, it is, says *Science*, stated that at atmospheric pressure, and a temperature of 62 deg. Fah., 1 lb. of the gas occupies about 23 cubic feet, while 1 lb. of liquid ammonia would occupy only 36 cubic inches.

The Induction Balance in Surgery.—M. Trouvé has invented a very ingenious electric probe which when inserted into a wound indicates the presence of a foreign body, especially if it be a bullet, by closing an electric circuit and ringing an alarm bell. This instrument is, however, inapplicable in cases where it would be dangerous to probe, or where the perforation has partially healed up. Such a case is evidently that of General Garfield, the American President, and there appears to be some difficulty in telling the true locality of the missile. Professor Graham Bell, with that ardent desire to benefit the sufferer, which is characteristic of the whole nation, has suggested that the induction balance of Professor Hughes might be successful in indicating the true position of the ball, and in response to a telegram to that effect, Professor Hughes has promptly devised a modified form of the apparatus specially adapted for the purpose. Our readers will remember that this instrument is extremely sensitive to the neighborhood of small pieces of metal, although nothing tangible connects them, and it is hoped that by applying it to the surface of the patient's body the spot and probable depth of the ball will be ascertained. Should these hopes be realized a valuable instrument of research will have been added to the cabinet of the surgeon.

Electric Lighting on the Cunard Steamer "Servia."—The chairman of the Cunard Company is giving practical evidence of his faith in electric lighting by fitting the Cunard steamship Servia with 98 lamps. The contract is being executed by Swan's Electric Light Company. The 98 incandescent lamps are to be disposed in the following manner: Engine room, 20; propeller shaft tunnels, 10; grand saloon, 50, music room, 8; ladies' boudoir, 6; smoking room, 4. The requisite current will be obtained from a No. 7 "Brush" dynamo-electric machine, the driving of which will be done by a special engine made by Messrs. John Fowler and Co., Leeds.

An Absolute Sine Electrometer.—The absolute electrometer of Sir William Thomson is a very elaborate instrument for measuring the electromotive force or mechanical attraction between the two poles of a battery in absolute units; but it is troublesome to use, and it can only give the result for a comparatively large battery. Professor Minchin has just constructed an absolute sine electrometer which combines convenience of manipulation and sensitiveness of action. It will in fact measure the electromotive force of a single cell. The apparatus chiefly consists of two parallel metal plates hung from a frame in such a way that they can be tilted through an angle from the vertical. One of the plates has an aperture cut in its middle, and this hole is very nearly closed by a movable trap or shutter suspended by two fine platinum wires from the upper edge of the perforated plate. The trap rests against finely pointed stops, and is brought flush with the inner surface of the plate. The opposite poles of the battery to be measured are connected to these opposite plates, which are then tilted from the vertical until an angle is found at which the attraction of the entire plate on the movable trap is exactly balanced by the weight of the trap. When this is so the electromotive force is proportional to the sine of the angle of displacement. This angle, the area of the trap, and the distance between the two plates, are the required quantities, and the electromotive force is calculated from them by a well-known formula.

The Sun Electric Lamp.—*La lampe soleil*, as it is termed, is a new French electric lamp of considerable promise and some novelty. The light is formed by boring two converging holes into a small block or brick of marble, and inserting into these two carbon rods. The rods are separated at their points by a partition of the marble, and they nearly penetrate through the block. Their upper ends are connected to the dynamo-electric machine, and the current in traversing the wall of marble between their points makes it white hot. The carbons are slowly consumed, the gas escaping by the bore-holes, which are wider than the rods, and they are fed to the arc by their own gravity. The light is emitted by the bottom of the brick, which becomes calcined, and is of a mellow lustre like the sunshine. The cost is said to be only a sou per hour, the carbons consuming at the rate of a centimeter in that time. Already *la lampe soleil* has been introduced into several places in Paris, including the mayor's residence, and it will form a feature of the forthcoming exhibition. It is the invention of MM. Clerac and Bureau; but it reminds us of the electro calcic lamp patented by Mr. Wentworth L. Scott in 1878, wherein a block of lime or other earth is interposed between the electrodes of the arc. Mr. Scott did not arrange his apparatus like the sun lamp; but his intention was, we understand, to heat a piece of lime white hot by the current, just as it is heated by the mingling gases in the Drummond lime light.

An Iodine Cell.—At a recent meeting of the Royal Society of Ediburgh, Professor P. G. Tait described a new form of constant battery devised by Mr. A. P. Laurie. Its leading merit is that it combines the simplicity of a single fluid cell with an electromotive as constant as that of the best double fluid cells. The liquid is a solution of iodine in iodide of zinc; the function of the dissolved iodine being to prevent polarization and consequent weakening of the electromotive force. The negative plate is of carbon and the positive of unamalgamated zinc. When the cell is not at work the zinc should be removed from the iodine to prevent local action. As tested by Thomson's quadrant electrometer, the electromotive force of this combination is very approximately one volt; and such is its constancy that after half an hour's short-circuiting the electromotive force was hardly at all diminished.

VAN NOSTRAND'S

ENGINEERING MAGAZINE.

NO. CLV.—NOVEMBER, 1881.—VOL. XXV.

THE ACTUAL LATERAL PRESSURE OF EARTHWORK.

By BENJAMIN BAKER, M. Inst. C.E.

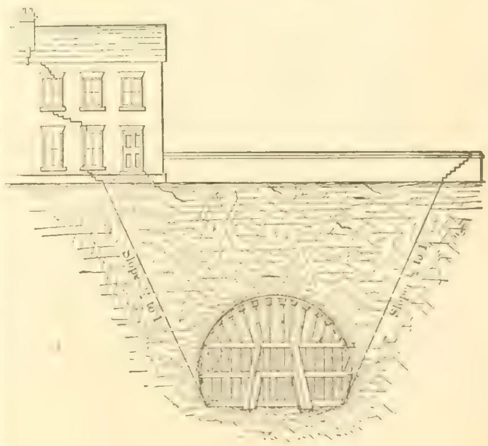
Proceedings of the Institution of Civil Engineers.

II.

Having thus briefly reviewed some direct experiments on the actual lateral thrust of earthwork, the author proposes to revert to the consideration of indirect experiments, dealing first with a few of those arising on the 34 miles of deep-timbered trenches and other works of the "underground" railway.

In tunneling very valuable evidence was afforded of the direction of the line of least resistance in a mass of earthwork. From the coming down of the crown bars, the changing of props, the crushing of timber, the compression of green brickwork and other causes, a settlement of from 6 to 8 inches usually occurred overhead, with a general draw of the ground towards the working end of the tunnel and the formation of fissures, attaining a maximum size where the line of least resistance cut the surface. Even when the settlement was slight, fissures were invariably observed in advance of the working end, and in continuous lines running parallel with the tunnel. The slope of these fissures was so uniformly at the angle of ½ to 1, measuring from the bottom of the excavation (Ex. 24, Fig. 5), that the resident engineer professed to be able to foretell with certainty where a building or fence wall, standing over the tunnel, would crack most. Assuming this ½ to 1 to represent Coulomb's line of least resistance, then the corresponding natural slope of repose of the material would appear to be 1⅓ to 1, which is considerably steeper than what it was in fact.

Fig.5



There is nevertheless a closer accord than usual between theory and fact in the instance of the several miles of fissures, which occurred during the construction of the tunnels of the Metropolitan railway. In other instances, such

as the failure of ill-devised timbering, or the pushing forward of a retaining wall, by heavy clay pressing against its lower half, this accord was not always exhibited. In some cases no previous fissures have occurred, but a wedge of 1 to 1 has at once broken off and gone down with the timbering, whilst in others the fissure has appeared immediately at the back of the wall; indeed in one instance, for several consecutive weeks, the author was able to pass a rod, 15 feet long, between the wall and the apparently unsupported vertical face of the ground behind it. The corresponding theoretical slope of repose would thus appear to be horizontal in one case and vertical in the other, which is sufficient evidence of the necessity of giving but a qualified assent to any theoretical deduction affecting the line of least resistance in earthwork.

A very fair notion of the relative intensity of lateral and vertical pressure in earthwork is often obtained in carrying out headings. The heading for the Campden Hill tunnel of the Metropolitan railway is a case in point (Ex. 25). The ground consisted of sand and ballast, heavily charged with water, overlying the clay through which the heading was driven, at a depth of 44 feet from the surface. After the heading had been completed some months, the clay became softened to the consistency of putty by the water which filtered through the numerous fissures, and the full weight of the ground took effect upon the settings. Both caps and side trees showed signs of severe stress throughout the entire length of the heading, and the occasional fractures in the roof and sides indicated that the timbers were proportionately of about the same strength, or rather weakness. The caps were of 14-inch square balks, with a clear span of 8 feet, and the sides of 10-inch square timber, with a clear span of 9 feet. Their respective powers of resistance per square foot of poling boards, supported, would therefore be as $\frac{14^3}{8^2} : \frac{10^3}{9^2} = 3\frac{1}{2} : 1$.

Now if one thing is settled by experience beyond all question, it is that the superficial beds of London Clay, sodden, as in the present case, with water, will not take a less slope of repose than 3 to 1. The average weight of the wet ground over the heading being about 1 cwt. per cubic foot, the theoretical lateral pressure on the side trees, at a mean depth of 48 feet from the surface, would be (see table) $= 48 \times 0.52 \times 1$ cwt. $= 25$ cwt. per square foot, and upon the caps $= 44 \times 1$ cwt. $= 44$ cwt. per square foot, or 1.76 time greater. But the side trees, as has been seen, had only $\frac{1}{3.5}$ of the strength of the caps, so the irresistible conclusion is that the actual lateral pressure of the earthwork in this instance did not exceed one-half of that indicated by theory.*

It is readily shown that the full weight of the ground came upon the settings. Thus, assuming it to do so, the weight upon the caps would be $= 44$ cwt. $\times 8$ feet clear span $\times 3.5$ feet distance apart of the settings $= 1{,}232$ cwt., and taking the effective span at 9 feet, the breaking weight, upon the basis of Mr. Lyster's experiments on balks of similar size and quality, would be $\frac{2 \times 14^{3\prime\prime} \times 2.03 \text{ cwt.}}{9'} =$ 1,240 cwt.; hence the occasional fractures of the balks are fully accounted for. Indeed, the heading would have entirely collapsed, in the course of time, had not the roof been supported by intermediate props practically quadrupling its strength.

In the early days of the construction of the Metropolitan railway, a definite type of timbering had not been arrived at, and some remarkably light systems were tried at times. The lightest the author remembers was the timbering of the 14-feet wide gullet at Baker Street station (Ex. 26). Here the soil cut through was made up of about 8 feet of yellow clay and gravel, 7 feet of loamy sand, 7 feet of sharp sand and gravel, full of water, and 4 feet of London clay at the bottom of the gullet. The timbering of the lower half consisted of 9-inch by 3-inch walings, 3 feet apart from center to center, in 12-feet lengths, with $\frac{3}{4}$-inch poling boards at the back. With one-half the distributed breaking load, the deflection of this 3-inch deep beam at the span of 12 feet would be at least 4 inches, whilst the ultimate deflection would be measured by feet. As the walings did not bend nearly as much as 4 inches, it will be a liberal estimate to assume that the actual lateral pressure of

* See also "Zur Theorie des Erddrucks," Weyrauch Zeitschrift für Baukunde, vol. i., p. 192,

the earthwork was equal to half the distributed breaking weight of the waling. Having reference to the quality of the timber, this may be estimated at $\frac{3^{2\prime\prime} \times 9^{\prime\prime} \times 2.6 \text{ cwt.}}{12^{\prime}\ 0^{\prime\prime}} = 17.6$ cwt.; and since the area of the poling boards supported by each waling was 36 square feet, it follows that the lateral pressure of the earthwork could not have exceeded 55 lbs. per square foot. But the depth of the bottom waling below the surface was 23 feet, or, neglecting the clay, and taking only the sharp sand and ballast charged with water, the depth would still be 20 feet, and the weight of fluid corresponding to the 55 lbs. per square foot pressure no more than 2.75 lbs. per cubic foot.

It will be remembered that the natural slope of the sand and ballast in Lieutenant Hope's retaining-wall experiments was about $1\frac{1}{3}$ to 1, and that the actual and theoretical corresponding fluid pressures were respectively 10.3 lbs. and 23.6 lbs. per cubic foot. In the case of the gullet, the natural slope of the ballast and sand would similarly be not less than $1\frac{1}{3}$ to 1, and yet the fluid pressure could not have exceeded 2.75 lbs. This one fact, therefore, is sufficient to prove that the universal assumption of the pressure of earthwork being analogous to that of fluid, and proportional to the depth, is one of convenience rather than truth. The explanation of the singularly small lateral thrust of the ballast in the present case is to be found in the fact that the ballast was lying between, and partially held back by, the two relatively tenacious layers of loamy sand and clay. As an extreme example of the same kind of action (Ex. 27), the author may state that he once applied to a wooden box full of sand a pressure equivalent to a column of that material 1,400 feet high before the box burst. On the fluid hypothesis, the lateral pressure would have been 1,400 feet × 23.6 lbs., or about 15 tons per square foot; but of course a few lbs. would have burst the box, and the sand was retained by being jammed between the bottom and lid of the little deal box—the equivalents of the tenacious strata in the gullet.

In shafts the stress on the timbering is far less than in a continuous trench or heading, by reason of the frictional adhesion and tenacity of the adjoining earth. Thus (Ex. 28) at a depth of between 40 and 50 feet, 10-inch square timbers, 4 feet 6 inches apart, proved of ample strength to support the sides of a 12-feet square shaft, though the same sized timbers at the reduced distance of 3 feet 6 inches apart, failed, as has been seen, to support the sides of a 9-feet square heading.

After the experience of several rather troublesome slips, light timbering was abandoned, and a type which proved to be of ample strength to meet all the contingencies of heavy ground, vibration from road traffic, and the surcharge of lofty buildings, was adopted. In this type (Ex. 29) the 14-feet walings increased in scantling to 12 inches by 7 inches, were spaced 7 feet apart, and strutted at each end and at the center. At one-half the breaking weight the supporting power of the walings would be about $\frac{7^2 \times 12 \times 3 \text{ cwt.} \times 112}{6.5^2 \times 7} = 670$ lbs. per square foot, and as the depth of the excavation was in some instances as much as 36 feet, this would correspond to a fluid pressure of 18.6 lbs. per cubic foot. With ground weighing 112 lbs. per cubic foot, and a slope of repose of $1\frac{1}{2}$ to 1, the theoretical lateral pressure would be 32 lbs. per cubic foot; and when it is remembered that this does not include any allowance for the surcharge due to contiguous buildings, and that the stress on the timber is taken at fully half the breaking weight, it is clear that the average actual lateral pressure of the earthwork must have been less than half that indicated by theory.

On the extensions of the Metropolitan railway, the same type of timbering was adopted, but the walings were generally 9 inches by 4 inches, and spaced 3 feet apart. The supporting power, upon the same basis as in the last instance, would be about 430 lbs. per square foot. In most cases this strength proved to be sufficient, but in a few instances the walings broke, or showed such signs of distress that additional support had to be given. This was the case in some of the deep trenches along the Thames Embankment, where heavy wet silt was traversed. Near Whitehall Stairs (Ex. 30) the trenches were 40 feet deep, so the elastic strength of the timbering was

only adequate to the support of a fluid pressure of 10.6 lbs. per cubic foot, or probably but one fourth of that theoretically due to the material; it is therefore no matter for surprise that the walings proved unequal to their work. The stability of the timbering in more moderate depths was, on the other hand, confirmatory of the general deductions

Fig.6

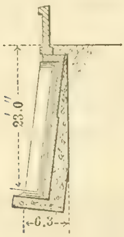
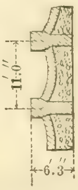


Fig.7



drawn from previous examples as to the wide divergence between the actual and calculated thrust of earthwork.

Turning now from the consideration of the temporary works of timbering to the finished and permanent structures on the underground railway, a similar variation in strength will be found to obtain. The lightest retaining wall on the line is that at the Edgware Road station yard (Ex. 31, Figs. 6 and 7). This wall is 23 feet in height from the top of the footing to the ground level, and has a maximum thickness of but 6 feet 3 inches at the base, out of which has to be deducted a panel 2 feet 6 inches deep. Calculating the moment of stability at the level of the footings and round a point 3 inches back from the face of the pier—which is a sufficient allowance for the crushing action on the brickwork—M=4.4 feet, × 8,800 lbs. = 38,720 foot pounds per lineal foot of wall. Dividing by $\frac{h^3}{6}$, then 19 lbs. per cubic foot is the weight of the fluid which would overturn this retaining wall. The ground supported is light dry sand, having a slope of repose of about $1\frac{1}{3}$ to 1, and consequently exerting a theoretical lateral thrust equivalent to a 24-lb. fluid. There is practically no tenacity in the soil, as the author remembers seeing demonstrated on one occasion when a horse and cart, approaching too near the top edge of the slope, broke it away and rolled together to the bottom of the 23 feet cutting. Although theoretically deficient in stability, and subject to heavy vibration from the two minutes train service, the wall has stood perfectly without exhibiting the slightest movement. Upon the basis of the results of actual experiments, and having reference to the character of the soil and other conditions, the factor of safety would appear to be about 2 to 1.

A far lower factor sufficed to secure the temporary stability of the dry areas at the station buildings previous to the erection of the arched roofs (Ex. 32). The arrangement at Sloane Square station is shown in Figs. 8 and 9. The joint stability of the front and back walls is the same as that of a solid rectangular wall having a thickness equal

Fig.8

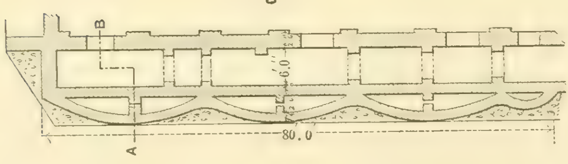
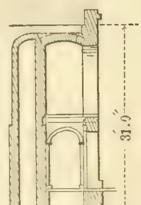


Fig.9



Section on line A B.

to $(2.4 \times 2.5 + 3.8 \times 5.2)^{\frac{1}{2}} = 5.1$ feet, or say $\frac{1}{6}$ of the height. A fluid pressure of about 9 lbs. per cubic foot would upset such a wall, so the factor of safety, until the arched roof abutted against the dry areas, was only that due to the few 14-inch brick arches which tied the walls together with a certain amount of rigidity. This result would perhaps have surprised the author more had he not previously investigated many cases of

old timber wharves, in which the piles and planking had lost more than $\frac{3}{4}$ of their original strength from decay, and yet held on against a theoretically overpowering thrust of earthwork.

The relatively strongest wall on the Metropolitan railway system is at the St. John's Wood Road station (Ex. 33), and that has given considerable trouble. Though 8 feet 6 inches thick at the base, and backed up to a height of 16 feet only out of the total height of 21 feet 6 inches, and supported at the top by the thrust of the arched roof of the station, this wall moved over and forward to an extent which necessitated the immediate adoption of remedial measures.

It is a suggestive fact that, out of the 9 miles of retaining wall on the underground railway, the exceptionally weak wall should show no movement either during or after construction, whilst the exceptionally strong wall, though having six times the stability of the former, should fail. If an engineer has not had some failures with retaining walls, it is merely evidence that his practice has not been sufficiently extensive; for the attempt to guard against every contingency in all instances would lead to ruinous and unjustifiable extravagance, and be indeed as ridiculous a proceding as the making every soft clay cutting at a slope of 10 to 1, because in a few places such cuttings happen to slip down to that slope.

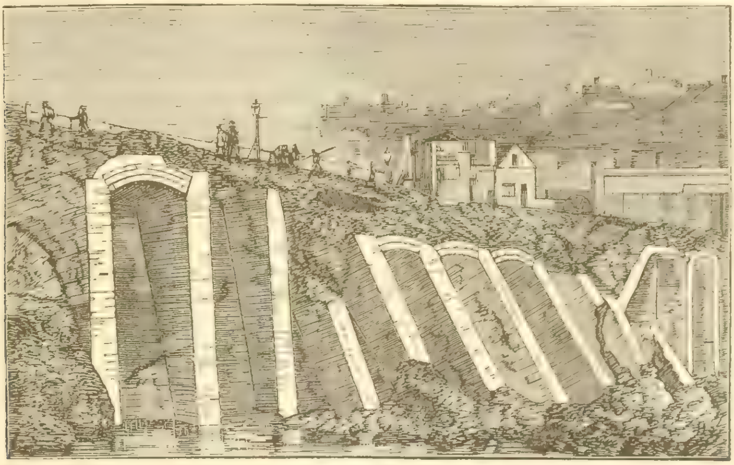


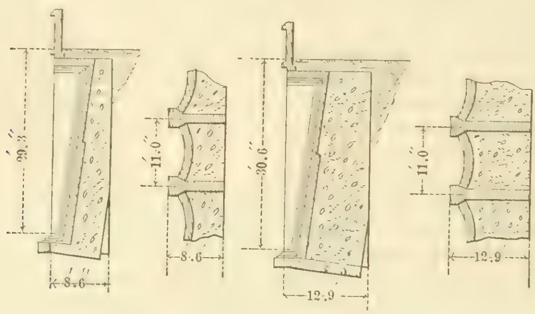
Fig. 10.

The moment of stability per lineal foot $M=73{,}000$ foot pounds, consequently dividing by $\frac{16^3}{6}$ the fluid resistance is 107 lbs. per cubic foot, or allowing for the thrust of the arched roof of the station, considerably greater than that of a perfect fluid having the same density as the ground supported. It is not contended that such a pressure ever occurred upon the wall, although the ground is heavy yellow clay. The failure arose from causes which will be referred to more generally hereafter, and the case is only mentioned as a signal instance of the futility of hoping to reduce the engineering of retaining walls to the form of a mathematical equation.

In two instances comparatively heavy retaining walls have failed on the Metropolitan railway. During the construction of the line, the wall on the west side of the Farringdon street station, (Ex. 34), failed bodily by slipping out at the toe and falling backwards on to the slope of the earthwork (Fig. 10). This wall (Figs. 11 and 12) was 29 feet 3 inches high above the footings, and 8 feet 6 inches thick. The ground consisted of about 17 feet of made ground, 3 feet of loamy gravel, and 9 feet of clay. At a distance of 15 feet from the back of the wall, and at a depth of 15 feet from the surface of the road, was the Fleet Sewer—a badly constructed and much

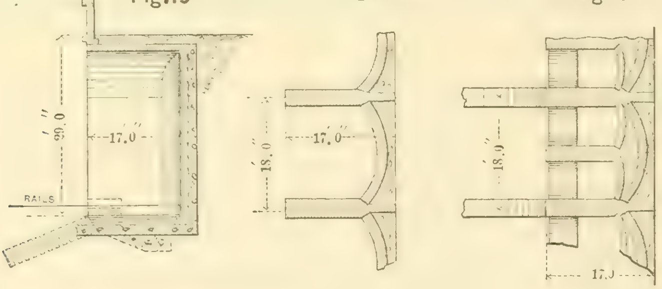
broken brick barrel, 10 feet 6 inches diameter and 3 rings thick. It was believed that the leakage from the sewer induced the failure of the wall, but in reconstruction both wall and sewer were strengthened. The latter was made 4 rings thick in cement, and the former (Ex. 35) was increased in thickness to 12 feet 9 inches (Figs. 13 and 14). Originally the stability was equal to the resistance of a fluid pressure of 24 lbs. per cubic foot, and, as reconstructed, to 54 lbs.

Fig.11 Fig.12 Fig.13 Fig.14



On the opposite side of the same station yard the ground was retained by a line of vaults (Ex. 36, Figs. 15 and 16), 29 feet high above the footings, and 17 feet deep—or double the original thickness of the wall last referred to. Although the resistance to overturning was greater in the proportion of 62 lbs. to 24 lbs. per cubic foot, the vaults some years after construction came over 15 inches at the top, and slid forward considerably more. The movement when once fairly commenced was rapid and alarming, as a mass of densely inhabited houses was within 20 feet of the back of the vaults. Steps were promptly taken to strengthen the work, by building intermediate piers and doubling the thickness at the back (Ex. 37, Fig. 17). This arrested the movement for a few months, when the vaults, whose stability had been thus increased to 93 lbs. per cubic foot, again began to go over and slide forward. It was clear that mere weight would not insure stability, so 3-feet square brick struts were carried at intervals from the toe of the piers across and under the railway to the retaining wall of the low-level line traversing the station yard, at a distance of about 34 feet from, and 8 feet below, the level of the footings of the vaults.

Fig.15 Fig.16 Fig.17



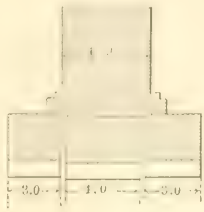
The soil in the preceding instance consisted of about 12 feet of made ground overlying the clay, and, as in the former case, a sewer was to be found rather close to the back of the work. West-

ward of the vaults, the clay encountered in the construction of the line was hard blue clay, requiring the use of a pick, and portions of the temporary cuttings in the station yard, on the site where the vaults were subsequently built, stood fairly for many months at a slope of $1\frac{1}{2}$ to 1. At one point, however, troublesome slips occurred, and even a 2 to 1 slope had to be piled at the toe to prevent forward movement. It was at this point that the vaults were subsequently found to be most dislocated.

In neither of the above cases was failure due to a deficient moment of stability in the wall, and therefore the fact of their failure does not in any way conflict with the results of the experiments previously set forth. In each case water at the back of the wall was as usual the active agent of mischief—not in thrusting the wall forward by hydrostatic pressure, but in softening the clay and affording a lubricant, so that the resistance was reduced to a sufficient extent to enable the otherwise innocuous lateral pressure of the earthwork to tilt and thrust forward the wall.

A costly, but conclusive, experience of this softening action was obtained in the instance of the central pier to the double covered way on the District railway near Gloucester Road station (Ex. 38). The weight per lineal foot was 21 tons per foot run of pier, and 4 feet 9 inches was spread out by footings and concrete to a base of 10 feet; hence the pressure on the ground was 2.1 tons per square foot. In a similar construction near Aldersgate the load was 25 tons, and the width of base 8 feet 3 inches, giving the increased load of 2.9 tons upon the foundations. At the Smithfield market the author did not hesitate to place a column carrying 435 tons upon a 12-feet-square base, which is equivalent to a load of 3 tons per square foot; and in the Euston Road, the side wall of the covered way has a load of 15 tons per lineal foot on a 4-feet-wide base, which is at the rate of $3\frac{3}{4}$ tons per square foot. In all instances the foundation was clay, of apparently equal solidity, and in every instance but the first no settlement at all occurred. For some years no settlement was observable in that case either, but ultimately, after an accidental flooding of the line, and permanent accumulation of water near the foundations, owing to the line being below the limits of natural drainage, and the pumping being neglected, cracks were observed in the arches, and on examination the concrete and footings of the central pier were found to be fractured, as shown in Fig. 18. The load of 21 tons per lineal foot was thus imposed upon a base only 4

Fig. 18



feet wide, and the softened clay proved unable to sustain the pressure of upwards of 5 tons per square foot. Considerable difficulty was experienced in checking the movement when once established. The center pier was underpinned with brickwork in cement, but the footings, though of exceptional strength, were again sheared off, and it was found necessary to use 6-inch York landings.

This failure shows the advisability of making concrete foundations of sufficient transverse strength to distribute the weight uniformly over the ground. As the result of experiment, the author is of opinion that the ultimate tensile resistance in a beam of good cement or lias lime concrete, is about 100 lbs. per square inch, and in a beam of good brickwork in cement as much sometimes as 350 lbs. per square inch.* Taking the former value (Ex. 39), a 12-inch thick concrete foundation, projecting 12 inches from the face of a wall, would break with a distributed load $=\frac{12^2\times 100}{6\times 6}=4{,}800$ lbs.; or, say, 2 tons per square foot. With a pressure upon the foundation of, say, 3 tons per square foot, and a factor of safety of 2, the thickness of a concrete foundation would therefore be $\sqrt{\frac{3 \text{ tons}\times 2}{2 \text{ tons}}}=1.73$ time the amount of

* *Vide* "The Strength of Brickwork." By B. Baker. "Engineering," vol. xiv.

its projection beyond the face of the pier or wall, and the author would not advise a less thickness being used when the foundation rests on plastic clay.

Water naturally gravitates to the foundation of a retaining wall, and a softening occurs. Owing to the lateral thrust of the earthwork, the pressure on the foundations is not uniform, and instead of settling uniformly, the outer edge descends fastest and the top of the wall is thrown outwards. The same softening reduces the clay to a condition in which it is easily ploughed up by the advancing wall, and the water acts as an admirable lubricant in diminishing the friction between the bottom of the wall and the clay on which it rests. These elements are exceedingly variable in their nature, and it is practically impossible to foretell the extent of their influence in each individual case.

In tunneling, clay may be the best or the worst of materials—almost self-supporting, or pressing with irresistible force on the crushing timbers and brickwork. It may be taken for granted that in good ground bad work will occasionally creep into tunneling, however close the inspection. How good a material clay can be was enforced upon the author's attention once in renewing a short length of defective tunnel lining, when on cutting down the work it was found that for some 50 feet the side wall, instead of being 2 feet 6 inches thick as intended, consisted merely of a skin of brickwork 9 in inches thick on the face, with a number of dry bats thrown in loosely behind this thin face wall to fill up the space excavated. This tunnel (Ex. 40) was loaded with a weight of 46 feet of clay over the crown, but no measurable settlement had taken place ten years after completion, and it was rather by sounding the side wall, than by the observance of cracks, that a suspicion was raised as to its solidity. If the full weight of the ground had come upon the tunnel as it did upon the heading (Ex. 25), the pressure upon the side wall would have been 45 tons per lineal foot, or practically double the strength of the 9-inch work as determined by experiment.

Of course the clay in this case was hard blue clay, which had not been affected by the action of air and moisture. As explained by the Rev. J. C. Clutterbuck, many years ago, the superficial layers of the London clay are yellow, because the protoxide of iron is changed into a peroxide by the action of air and moisture in the disintegrated mass, and it is the yellow clay, therefore, which is the dread of the engineer. As good an example as any of the difference between the two materials was afforded forty years ago, in the well-known slip which occurred in the 75-feet-deep cutting at New Cross, when nearly 100,000 tons of yellow clay slipped forward on the hard smooth surface of the shale—like underlying blue clay, and buried the entire line for a length of more than a hundred yards to a depth of 12 feet.*

Owing to a misunderstanding, a section of concrete wall designed by the author to form one side of a running shed, and to retain the earthwork in a 13-feet cutting through light-made ground, was adopted also in a similar case, but where the ground was heavy wet clay, and the cutting 30 feet deep (Ex. 41). A wall 13 feet in height from formation to coping, and only 3 feet 3 inches thick at the base, had thus to sustain a surcharge of 17 feet. As the slope of repose was at least 1½ to 1, the lateral thrust was theoretically equivalent to a fluid pressure of about 70 lbs. per cubic foot, whereas a pressure of less than one-third that intensity would have overturned the wall. The latter, nevertheless, held up the ground fairly for some months, though the nature of the soil was such that it ultimately became necessary to add strong counterforts to the wall, and to reduce the slope of the cuttings generally to 2 : 1.

On the Thames Embankment heavy clay filling was in places cut through by the District railway, and in several instances the light side walls of the covered way were thrust over a few inches at the top before the girders were bedded (Ex. 42). The side walls were eighteen feet in height from the invert to the ground level, and 5 feet 6 inches thick, with panels 5 feet 6 inches wide, by about 2 feet 9 inches deep, and piers 2 feet 6 inches wide. A fluid pressure of 16 lbs. would overcome the stability of these walls, but, though subject to the pressure of the

* *Vide* Minutes of Proceedings Inst. C.E.. vol. iii., p. 139.

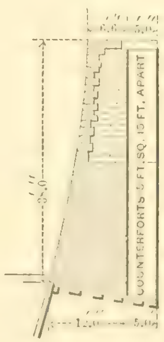
heavy clay filling, none of them failed. The existence of an undue pressure was, however, manifested by the thrusting forward of the green brickwork during the few weeks that the walls were left unsupported by the girders.

The retaining walls, at the approach to Euston Station, afford a good illustration of the impossibility of making any reasonable approximate estimate of the possible lateral thrust of yellow clay, or of stating positively that no movement will ever occur. These walls, soon after construction, were forced out in an irregular way at the top, bottom, or middle, but on pulling them down, the clay behind appeared to be free from fissures and to stand vertical. Cast-iron struts were subsequently put in between the opposite retaining walls; and although General Burgoyne, who had given much attention to the subject of revetments, prophesied at the time that they would be removed in a few years, "when the ground had become consolidated," the struts still remain, and the walls still give signs of severe and increasing stress.

It is not only London clay that proves so embarrassing to engineers. In a recent Paper* particular attention was called to the treacherous nature of some boulder clay which, "although so tough and tenacious as to give the utmost difficulty in excavation, after a short exposure became soft and pasty in the winter, often jolting down the slurry." Examples were given of formidable slips in this material, in contrast with which the author would point to the comparatively slow wasting of the huge boulder clay cliffs near the mouth of the Tyne, a matter which he had occasion to investigate very closely in connection with the Duke of Northumberland's lands in that district. From a comparison of surveys extending over a period of one hundred and fifty years, it appeared that the wasting of the cliff was very slow, and due solely to the wash of the waves at its base. At no time was the slope of repose of this 105-feet-high cliff more than 1 to 1, and in places it stood for years at an average slope of less than $\frac{3}{4}$ to 1. With his experience of North London clay, the author was startled to find people contentedly living in houses partially overhanging the brow of this steep and ragged cliff, but the stability of the clay was so great, and the wasting so uniform, that the fact of the outhouses being at the bottom of the 100 feet slope, and the main building at the top, did not appear in any way to disturb the equanimity of the householders.

The failures of dock walls, though numerous and instructive, afford no direct evidence as to the actual lateral pressure of earthwork, because in practically every instance the failure is traceable to defective foundations. The author cannot recall any case in which a dock or quay wall founded on rock has overturned or moved forward, though on other foundations a movement to a greater or lesser extent is so much the rule that Voisin Bey, the distinguished engineer-in-chief of the Suez Canal, once stated to the author that he could name no exception to it, since he had failed to find any long line of quay wall, which on close inspection proved to be perfectly straight in line and free from indications of movement. A brief examination of some instances of the failures of dock walls will show how powerfully unknown practical elements affect theoretical deductions in such cases.

Fig. 19



A well-known and often cited case is that of the original Southampton dock wall, constructed now some forty years ago (Ex. 43, Fig. 19). This wall, 38 feet in height from the foundation to the coping, was built on a platform of 6-inch planks, resting on a sandy and loamy bottom. Before the water had been let

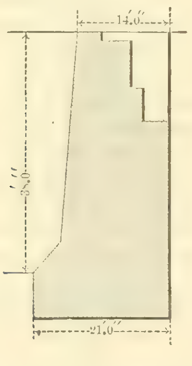
*Vide "Earthwork Slips," Minutes of Proceedings Inst. C. E,, vol. lxiii,, p. 280 et seq.

into the dock, or the backing carried to the full height, the wall moved forward in some places as much as three feet, but came over hardly anything at the top. When the water was let into the dock, the filling behind becoming saturated, the pressure on a receding tide exaggerated, and to secure stability it was found necessary to discontinue the filling at some distance below the full height of the wall, and to substitute a timber platform.

The thickuess of this wall at the base is 32 per cent. of the height between the buttresses, 45 per cent. at the buttresses, and a rectangular wall containing the same quantity of material would have a thickness equal to 26 per cent. of the height. Though the base is wide, the weight is light as compared with most other dock walls, and the tendency to slide forward is therefore greater. If founded on a rock bottom, a fluid pressure of about 40 lbs. per cubic foot would have been required to overturn the wall, but of course a fraction of this pressure would suffice to make it move forward on the actual bottom.

The conclusion drawn by Mr. Giles, M. Inst. C. E., the engineer of the docks, from this and other failures is, that the quality of a dock wall is of little consequence compared with the quantity, and

Fig.20

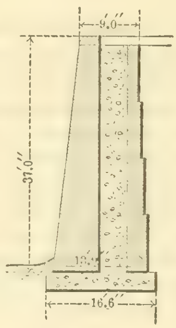


that it ought to be sufficiently strong not only to hold any amount of any kind of backing put against it, but to carry a head of water equal to its height if it were left dry on the other side.*

These principles have been adhered to in the recent extension of the Southampton docks (Ex. 44, Fig. 20). Here the wall is founded on a mass of concrete 21 feet wide; the effective thickness at base is about 45 per cent, and the mean thickness 41 per cent. of the height. A fluid pressure of from 60 to 70 lbs. would be required to overturn this wall if on a hard foundation, and probably as much to make it move forward, unless the bottom were of clay or of other unfavorable material. Mr. Giles has found even a heavier wall slide, when founded on a thin layer of gravel overlying clay. In the earlier wall, if the co-efficient of friction of the base on the ground were less than $\frac{2}{3}$, the wall would slide rather than overturn; but in the latter wall, without buttresses, any co-efficient exceeding $\frac{1}{2}$ would be sufficient to prevent sliding.

For comparison with the above, the section of the east quay wall of the Whitehaven dock may be next referred to (Ex. 45, Fig. 21). Having the same

Fig.21



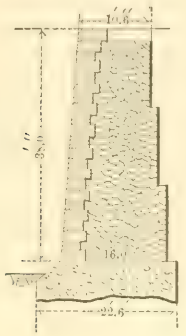
height as the Southampton dock wall, the thickness at the base is but 37 per cent of the height, the mean thickness 31 per cent., and the concrete foundation 16 feet 6 inches, instead of 21 feet wide. This wall has stood perfectly, though it would fail to resist the head of water mentioned by Mr. Giles, but would be overturned by a fluid weighing from 45 to 50 lbs. per cubic foot. During construction, weep holes were, however, left in the walls to relieve them of hydrostatic pressure.

Another dock wall of the same height as the preceding ones, is that of the Avonmouth dock (Ex. 46, Fig. 22). In this instance the thickness is 42 per cent.

* *Vide* Minutes of Proceedings Inst. C. E., vol. lv., p. 52.

of the height, and the concrete base 22 feet 6 inches wide, dimensions which, with a good foundation, would enable the wall to stand a full hydrostatic pressure at the back. Owing to the treacherous nature of the bottom, a long length of this wall nevertheless slipped forward at one point as much as 12 feet 6 inches, and sunk 4 feet 6 inches without the latter being affected, whilst at another

Fig.22

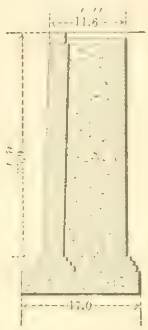


point, where there was no forward movement, the wall came over about 1 foot 8 inches. When the failure occurred, the foundation rested on apparently stiff blue clay, but in subsequent portions the concrete was carried down through the clay to the sand.* On the east side of the dock, though the walls were founded at an average depth of no less than 9 feet below the bottom of the dock, they still moved forward in the mass some 15 feet 6 inches, and sunk 7 feet 6 inches, The filling was carefully punned in layers, with material which seems to have stood fairly at a slope of $1\frac{1}{2}$ or 2 to 1, so that the wall theoretically possessed an excess of strength, and yet, owing to the existence of conditions which it was impossible for the engineer to foresee, failures occurred as described.

A somewhat similar case of sliding forward occurred at the New South Dock, West India Docks (Ex. 47, Fig. 23). The wall is 35 feet 9 inches high from the top of the footings to the coping, and 13 feet, or 36 per cent. of the height, thick at the base. The concrete foundation is 17 feet wide, and 6 feet deep below the bottom of the dock, and the fluid pressure required for overturning would be about 45 lbs. per cubic foot. A coefficient of friction of less than $\frac{1}{2}$ would be sufficient to guard against sliding under this pressure, but owing to the existence of a thin seam of soft greasy silt between the hard strata of blue clay upon which the foundations rested, several portions of the wall slid forward. The original ground level was about 15 feet below the top of the dock wall, and the excavation stood fairly as a slope of 1 to 1. Favorable material for backing did not appear to be available.

The fact that the stability of a dock

Fig.23



wall depends far more upon the foundation than upon the thickness or mass of the wall itself, is well illustrated by the quay wall at Carlingford (Ex. 48, Fig. 24). With a height of no less than 47 feet 6 inches, the thickness of wall and width of foundation at the base are each but 15 feet, or less than 32 per cent. of the height, and the mean thickness is but 24 per cent. A lateral pressure of half that due to a hydrostatic pressure would probably suffice to overturn this structure.

In contrast with the preceding wall may be cited that of the dock basin at Marseilles (Ex. 49, Fig. 25). In both instances the foundation was good, and the wall rested immediately upon it without the interposition of any broad mass of concrete; but the French engineer, though the wall was but 32 feet high, made the thickness at the base no less than 16 feet 9 inches, or 52 per cent. of the height—an unusually large propor-

* *Vide* Minutes of Proceedings Inst. C. E., vol. lv., p. 15.

tion, which he was led to adopt in consequence of the stratification of the ground inclining towards the wall.

Perhaps one of the boldest and most successful examples of a lightly-proportioned wharf wall is that built by Colonel Michon in 1857 on the Moselle at Toul (Ex. 50, Figs. 26 and 27). With a height of 26 feet, and a batter of 1 in 20, the thickness of the wall through the counterforts is but 3 feet 7 inches at the base, and though the filling is ordinary material, having a slope of repose of $1\frac{1}{2}$ to 1, and the floods rise within 6 feet of the top of the coping, no movement whatever has occurred since the wall was built.

Fig.24

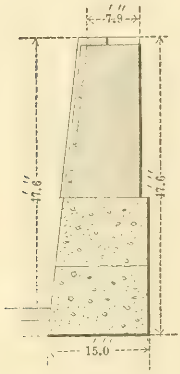


Fig.25

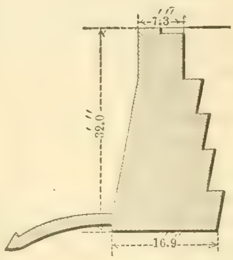


Fig.26

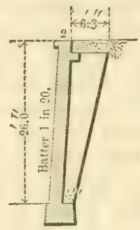


Fig.27

As striking a contrast as could be wished to the above light construction is found in Sir John Macneill's quay wall at Grangemouth harbor (Ex. 51, Fig. 28). Both walls are of about the same height, but whilst the mean thickness of the first is only 3.7 feet, or $\frac{1}{7}$ of the height, that of the second, inclusive of the mass of concrete backing, is no less than 23 feet, or, say, $\frac{6}{7}$ of the height.

One of the most troublesome cases of dock-wall failures was that at the Belfast harbor* (Ex. 52, Fig. 29). This wall was founded upon round larch piles 15 feet long, 10 inches in diameter at the top, and 4 feet 6 inches apart from center to center. Symptoms of settlement became apparent soon after the filling was commenced, and some remedial measures were attempted. The ground, however, was hopelessly bad, the slope of repose ranging from 3 to 1 to 6 to 1, and the backing material being equally bad, the light piling was inadequate to resist the thrust. Two years after erection a length of about 70 lineal yards of wall was overturned and carried forward into the middle of the dock entrance, the piles being sheared off about 6 feet be-

Fig.28

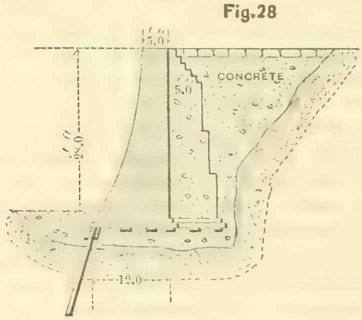


Fig.29

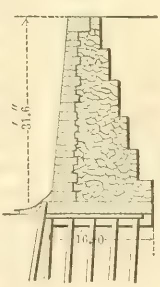
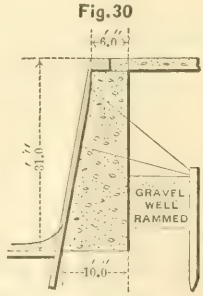


Fig.30



* *Vide* Minutes of Proceedings Inst. C.E., vol. lv., p. 31.

low the bottom of the wall. The height from the top of the pile to the coping is 31 feet 6 inches, and the thickness at the base 16 feet, or half the height. On good ground, therefore, the wall would have had an ample margin for stability.

A somewhat similar failure occurred in the instance of the original side walls of the lock chamber of the Victoria docks* (Ex. 53, Fig. 30). These docks were built at a time when little confidence was placed in concrete as a durable material for dock work, and consequently the walls were faced with cast-iron piling and plates, as in previous instances at Blackwall and elsewhere. The foundations were on a layer of gravel overlying the clay, but the face piling had little hold in the gravel, and the base of the wall itself was only some 30 per cent. of the height, hence, when the water was let into the dock, the hydrostatic pressure at the back of the lock wall forced it bodily forward into the lock, ploughing up the puddle in front of it, and breaking tie bolts and tie piles as it advanced. In reconstruction a solid concrete wall 20 feet thick, and having nearly treble the stability, was carried through the gravel down to the clay.

The wall of the Victoria Dock Extension Works, by Mr. A. M. Rendel, M. Inst. C.E. (Ex. 54, Fig. 31), has a thick-

Fig.31

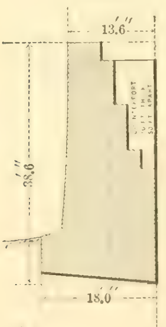
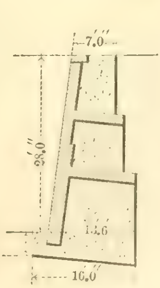


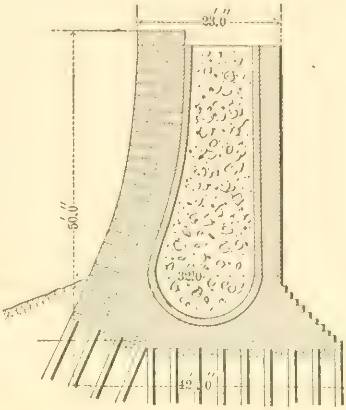
Fig.32



ness of about 50 per cent. of the height at the point where the 18-feet wide foundation meets what may be termed the body of the wall, and the wharf wall of Mr. Fowler's Millwall dock (Ex. 55, Fig. 32) has a maximum thickness of 13 feet 6 inches for a height of 28 feet from bottom of dock to coping, of practically the same ratio. Either or these walls would be capable of resisting the full hydrostatic pressure.

An early example of a successful wall on a very bad foundation is afforded by Sir John Rennie's Sheerness wall (Ex. 56, Fig. 33). The subsoil consisted of

Fig.33



loose running silt for a depth of about 50 feet, covered with soft alluvial mud, and the depth at low water was at some points as much as 30 feet. A piled platform about 42 feet in width, with sheeting piles on the river face, and 12-inch piles pitched from 3 to 4 feet apart over the whole area, and driven until a 15-cwt. monkey falling 25 feet did not move them more than ½ inch at a blow, was prepared, and upon this the wall, no less than 50 feet in extreme height and 32 feet in effective thickness at the base, was raised. In no case has any yielding or unequal settlement taken place, except in the instance of the basin wall, the cracks in which Sir John Rennie attributed to other causes than a failure in the foundation. Although the voids in the masonry were designedly filled in with grouted chalk and other light material, the Sheerness river wall has perhaps a greater moment of stability than any other wall in the world.

Another exceptionally heavy wall, more than a half century younger than the preceding, is that of the Chatham Dockyard Extension (Ex. 57, Fig. 34). The height from the bottom of the dock to

* *Ibid.*, vol. xviii., p. 462.

the coping is 39 feet, and the foundations are carried down to the loam gravel or chalk at a depth of 4 feet 6 inches below the bottom of the dock. The thickness of the wall is 21 feet at the base, or, say, ½ of the extreme height.

Fig.34

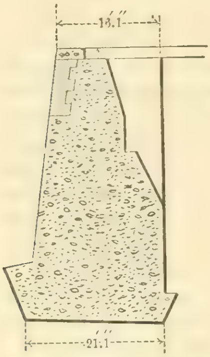


Fig.35

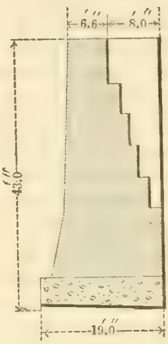
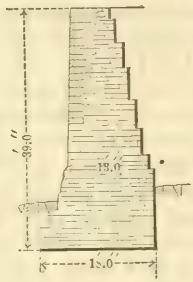


Fig.36



On a hard chalk bottom it would resist a fluid pressure of about 80 lbs per cubic foot.

Two examples of Liverpool dock walls, namely, that at the Canada half-tide basin, and that at the Herculanean docks, are given in Figs. 35 and 36. The former (Ex. 58) is 43 feet in extreme height, and 19 feet, or 44 per cent. wide at the base. The latter (Ex. 59) is 39 feet high, and 18 feet, or 46 per cent. wide at the footings, which rest on a marl bottom. A dock wall at Spezzia (Ex. 60) of somewhat similar proportions, the height being 41 feet, and the width at the bottom of foundations 23 feet, or 56 per cent. of the height is shown on Fig. 37.

Fig.37

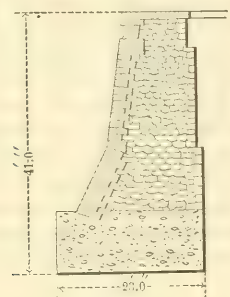


Fig.38

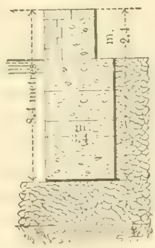
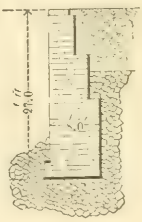


Fig.39



Walls made of large concrete blocks, resting upon a mound of rubble, have been constructed in many of the Mediterranean ports, generally with success, but occasionally with failure, as at Smyrna, where, owing to the great settlement, six and seven tiers of blocks had to be superimposed instead of four, as intended, and the quay wall had after all to be supported by a slope of rock in front extending up to within 7 feet of mean sea level, and seriously interfering with the use of the quays. The proportions arrived at by experience are a width of 9 meters at the top, and a thickness of not less than 2 meters for the rubble mound; a depth of 7 meters below the water line, and a thickness of 4 meters for the concrete block wall resting on the mound; and a minimum thickness of 2.5 meters, and a height of 2.4 meters for the masonry wall coping the concrete blocks.

At Marseilles (Ex. 61, Fig. 38), the

top of the rubble mound is only 6 meters below the water-line, so vessels occasionally bump; and the concrete block wall 3·4 meters, or 40 per cent. of the height, in thickness has proved rather less stable under the contingencies of working and the surcharge of buildings and goods than is considered desirable.

Examples are not wanting, however, of walls founded on rubble mounds where the thickness holds a smaller ratio to the height than the 42 per cent., considered necessary by the French engineers. Mr. Fowler has made concrete block walls in the Rosslare Harbor (Ex. 62) 42 per cent. of the height on the sea face, and but 28 per cent. on the harbor side, but cross walls at 50-feet intervals considerably strengthen the work. The inner wharf wall of the Holyhead new harbor, again (Ex. 63, Fig. 39), is 27 feet high and 8 feet thick, a ratio of under 30 per cent., but though stable, the line of coping is somewhat wavy on plan. The original wall of the West Pier at Whitehaven (Ex. 64, Fig. 40), is 42 feet 6 inches

Fig.40

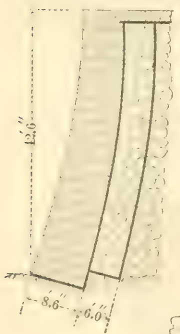
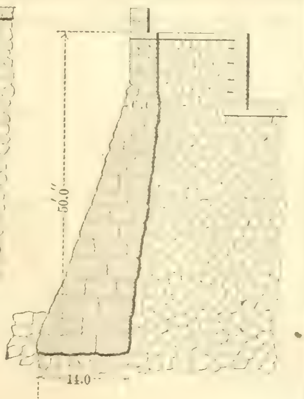


Fig.41



high, with a thickness of 8 feet 6 inches between the buttresses, which latter are 6 feet deep by about 4 feet wide and 15 feet apart; but the lightest of all, perhaps, is the dry masonry outer wall of the St. Katherine's breakwater, Jersey, (Ex. 65, Fig. 41), which is only 14 feet wide at the base for a total height of 50 feet, or a ratio of 28 per cent.

It must not be forgotten, of course, that the three latter walls have to support rubble hearting only, instead of sand and other material, having a much flatter slope of repose. Occasionally, as has been stated (Ex. 22), rubble will not stand at less than 1½ to 1; but at Holyhead and Alderney the slope of the rubble mound on the harbor side is only about 1¼ to 1. At Cherbourg it is 1 to 1, and at Leghorn the large concrete blocks are found to be stable at a slope of ⅔ to 1. By a very little care in selection, the thrust of a rubble filling may be reduced to a fraction of that arising from bad material, and indeed in the ordinary run of fishing piers in the North of Scotland, however great the height, the face wall of the rubble-hearted pier consists simply of stones from 3 to 4 feet in depth, laid dry to a batter of about 1 in 5. The north-east pier at Seham, again, has an inner wall 25 feet high, battering 1½ inch to the foot, and only 5 feet thick, and many similar examples are to be found at other points of the coast.

The most cursory examination of cases of failure cited above will serve to justify the statement that the numerous dock-wall failures do not afford any direct evidence as to the actual lateral pressure of earthwork. Thus, remembering General Burgoyne's battering wall, only 17 per cent. of the height in thickness, supported the heavy sodden filling at its back, no calculation is required to show that the 32 and 45 per cent. Southampton Dock counterforted wall, the 42 per cent. Avonmouth Dock wall, the 36 per cent. West India Dock wall, the 50 per cent. Belfast Harbor wall, and the 30 per cent. Victoria Dock wall, would all have stood perfectly had the foundation been rock, as in the instances of General Burgoyne's experimental walls, instead of the mud, clay, and silt which it actually was.

Not only the strength, but the type of cross-section, is singularly indicative of the small influence which theory and experiment have exercised upon the design of dock walls. If the early theorists and experimentalists were in accord upon one point, it was upon the immense advantage afforded by a counterforted wall. Lieutenant Hope was led by his experiments to conclude that if good counterforts were introduced, the merest skin of face wall would suffice for the portion

between them, and theorists of course arrived at the same conclusion, from a comparison of the moments of stability of rectangular blocks of masonry edgewise and flatwise. Nevertheless, in only one of the preceding dock walls, and that one forty years old, are counterforts introduced. In practice it was found that counterforts frequently separated from the body of the wall, and they were consequently regarded as untrustworthy. It is open to question whether this conclusion does not require reconsideration in these days of cheap, strong, and easily-moulded Portland cement concrete. Nothing but blasting would separate the counterforts from a good concrete wall. The author has used concrete in many varieties of structures, and as long back as fifteen years built a four-story warehouse, walls and floors, entirely of concrete, without the introduction of any iron girders. He is bound to admit, however, that by far the boldest and most thorough adaptation of the material to multifarious uses met with by him was in the instance of some farm buildings in an out-of-the-way district in Co. Kerry, Ireland. The small tenant-farmer and his laborers—none of whom were receiving over 11*s.* a week—without skilled assistance of any kind, had constructed dwelling-house, cattle-sheds, and hay-barn wholly of concrete. The cattle-shed was roofed with concrete arches of 15 feet span, 1 foot rise, and 4 inches thick, springing from octagonal concrete pillars 8 inches in diameter, spaced 15 feet apart from center to center. A layer of concrete constituted the paving, concrete slabs divided the stalls, the cattle fed and drank out of concrete troughs, the windows were glazed in concrete mullions, the gates hung on concrete posts, and the farmer seemed to regret somewhat that he had not adopted concrete doors and concrete five-bar gates.

Portland cement concrete being thus possessed of such great tenacity, there is no risk of counterforts separating from the body of a wall, but it by no means follows that there would be any advantage in using them in other than exceptional cases. In practice, as failures have shown, it is weight, with the consequent grip on the ground, rather than a high moment of stability, that is required in a dock wall. It may be asked, with reason why a bad bottom should affect the thickness of a retaining wall, or, in other words, why the foundation should not first be made good, and then a wall of ordinary thickness be built upon it. The answer, of course, is that if weight is required to prevent sliding, it is just as economical to distribute the material over the general body of the wall as to confine it to the foundations. It follows, therefore, that under the stated conditions the adoption of a counterforted wall would lead to no economy in material, whilst it would involve additional labor in construction.

A dock wall is subject to far larger contingencies than an ordinary retaining wall, and the required strength will be included only within correspondingly large limits. Hydrostatic pressure alone may more than double or halve the factor of safety in a given wall. Thus, with a well-puddled dock bottom, the subsoil water in the ground at the back of the walls will frequently stand far below the level of the water in the dock, and the hydrostatic pressure may thus wholly neutralize the lateral thrust of the earth, or even reverse it, as in the case of the inner retaining walls on the Soonkesala canal, some of which, though 35 feet in height, are only 2 feet thick at the top and 7 feet 6 inches at the base. On the other hand, with a porous subsoil at a lock entrance, the back of the walls may be subject, on a receding tide, to the full hydrostatic pressure due to the range of that tide plus the lateral pressure of the filling. Again, the water may stand at the same level on both sides of the wall, but may or may not get underneath it. If the wall is founded on a rock or good clay, there is no more reason why the water should get under the wall than that it should creep through any stratum of a well-constructed masonry or puddle dam, and under those circumstances the presence of the water will increase the stability by diminishing the lateral thrust of the filling. With rubble filling, assuming the weight of the solid stone to be 155 lbs. per cubic foot, and the voids to be 35 per cent., the weight of the filling would be 100 lbs. per cubic foot in air, and 59 lbs in water, and the lateral thrust will be that due to the latter weight.

If, however, as is perhaps more frequently the case, the wall is founded on a porous stratum, the full hydrostatic pressure will act on the base of the wall, and reduce its stability in practical cases by about one-half. Thus, the 30 ton concrete block walls on rubble mounds, at Marseilles and elsewhere, have the stability due to a weight of, say, 130 lbs. per cubic foot in the air, and 66 lbs. per cubic foot in sea water: but the rubble filling at the back of the wall, being similarly immersed, is also reduced in weight, and consequently thrust to a corresponding extent, so the factor of safety is unaffected.

In walls with offsets at the back, as in Figs. 25 and 36, and water on both sides, the stability will be much increased by the hydrostatic pressure on the top of the offsets, should the wall rest on an impermeable foundation. It is generally assumed, in theoretical investigations,* that the weight of earthwork superimposed vertically over the offsets should be included in the weight of the wall in estimating the moment of stability; but the author has found no justification in practice for this assumption. He has invariably observed that when a retaining wall moves by settlement or otherwise, it drops away from the filling, and cavities are formed. A settlement of but $\frac{1}{32}$ of an inch, after the backing had become thoroughly consolidated, would suffice to relieve the offsets of all vertical pressure from the superimposed earth, and the latter cannot therefore be properly considered as contributing to the moment of stability.

A wall with deep offsets at the back is not a desirable form where the foundation is bad, and where, consequently, the pressure over the foundation should be as uniform as possible, so that a settlement may take the form of a uniform sinking, and not a tilting forward of the coping by reason of the toe sinking faster than the back of the wall. A panelled wall, such as that shown on Figs. 11 to 14, though not admissible in dockwork, is on bad ground far less liable to come over than a wall with offsets at the back, and with a consequent concentration of weight at the front, where the conditions of a lateral thrust especially require that it should not be.

The latter conditions also indicate the expediency of adopting raking piles, as in Fig. 33, rather than vertical piles, as in Fig. 29, where a piled foundation is unavoidable. Thus, taking an ordinary case of dock wall, in which the factor of safety, as regards overturning, is 3, and the ratio of weight of wall to the lateral pressure of earthwork required to overturn it is $1\frac{2}{3}$ to 1, it follows that if the foundation piles are driven at the rate of 1 to $3 + 1\frac{2}{3} = 1:5$ there will be no transverse strain tending to break them off, as in the case illustrated by Fig. 29, and no tendency to plough up the soft ground in front of the toe of the wall.

If an engineer could tell by inspection the supporting power and frictional adhesion of every bit of soil laid bare, or see through 5 or 10 feet of earth into a "pot hole," or layer of slimy silt, he might avoid many failures, and even hope to frame some useful equations for obtaining the required thickness of a dock wall. Taking things as they are, however, it is hardly worth while to use even a scale and compass in such work, for being in possession of all the information obtainable about the foundation and backing, an engineer may at once sketch as suitable a cross section for the particular case as he could hope to arrive at after any amount of mathematical investigation. Something must be assumed in any event, and it is far more simple and direct to assume at once the thickness of the wall than to derive the latter from equations based upon a number of uncertain assumptions as to the bearing power of the foundations, the resistance to gliding, and other elements. This being so, it has often struck the author that the numerous published tables giving the calculated required thicknesses of retaining walls to three places of decimals, stand really on exactly the same scientific basis, and have the same practical value, as the weather forecasts for the year in Old Moore's Almanack. In both cases a pretence is made of foretelling what experience has shown can often not be known until after the event. One well-known authority gives young engineers the choice of five hundred and forty-four different thicknesses for a

* *Vide* "A Manual of Civil Engineering." By W. J. M. Rankine, p. 412.

simple vertical rectangular retaining wall, so that an unfortunate neophyte might not unreasonably conclude that the task before him was not to decide whether, say, a 32-feet wall should be 20 feet thick, as in Example 60, or 9 feet, as in Example 62, but whether it should be 14 feet 6 inches or 14 feet 5½ inches thick.

Although dock wall failures do not afford any data as to the actual lateral pressure of earthwork, a knowledge of the latter will enable much valuable information to be deduced as to the bearing power of soil and other matters from such failures, and the data so obtained will be applicable to other structures beside retaining walls. Knowing the actual lateral thrust, the coefficient of friction of the base of a wall which has been pushed forward on the ground can be at once deduced, but if the theoretical as distinguished from the actual thrust were introduced into the equation, the result would be valueless.

The aim of the author in the present paper has been to set forth as briefly as possible what he knows regarding the actual lateral thrust of different kinds of soil, in the hope that other engineers would do the same, and that the information asked for by Professor Barlow more than half a century ago may be at last obtained. Although the acquirement of the missing data would probably lead to no modification in the general proportions of retaining structures, since these are based upon dearly-bought experience, it is none the less desirable that it should be obtained; for an engineer should be able to show why he believes that a given wall will stand or fall. To assume upon theoretical grounds a lateral thrust, which experiments prove to be excessive, and to compensate for this by giving no factor of safety to the wall, is not a scientific mode of procedure.

Experience has shown that a wall ¼ of the height in thickness, and battering 1 inch or 2 inches per foot on the face, possesses sufficient stability when the backing and foundation are both favorable. The author, however, would not seek to justify this proportion by assuming the slope of repose to be about 1 to 1, when it is perhaps more nearly 1½ to 1, and a factor of safety to be unnecessary, but would rather say that experiment has shown the actual lateral thrust of good filling to be equivalent to that of a fluid weighing about 10 lbs. per cubic foot, and allowing for variations in the ground, vibration, and contingencies, a factor of safety of 2, the wall should be able to sustain at least 20 lbs. fluid pressure, which will be the case if ¼ of the height in thickness.

It has been similarly proved by experience that under no ordinary conditions of surcharge or heavy backing is it necessary to make a retaining wall on a solid foundation more than double the above, or ½ of the height in thickness. Within these limits the engineer must vary the strength in accordance with the conditions affecting the particular case. Outside these limits the structure ceases to be a retaining wall in the ordinary acceptation of the term. A 9-inch brick facing might secure the face of a friable chalk cutting which, if suffered to remain exposed to the action of the weather, would crumble down to a slope of 1 to 1, and a massive bridge pier, with an "ice-breaker" cutwater, might stand firm against an avalanche, but in neither case could the structure be fairly stated to be a retaining wall.

Hundreds of revetments have been built by Royal Engineer officers in accordance with General Fanshawe's rule of some fifty years ago, which was to make the thickness of a rectangular brick wall, retaining ordinary material, 24 per cent. of the height for a batter of $\frac{1}{5}$, 25 per cent for $\frac{1}{6}$, 26 per cent. for $\frac{1}{8}$, 27 per cent. for $\frac{1}{10}$, 28 per cent. for $\frac{1}{12}$, 30 per cent for $\frac{1}{24}$, and 32 per cent. for a vertical wall.

As a result of his own experience the author makes the thickness of retaining walls in ground of an average character equal to ⅓ of the height from the top of the footings, and if any material is taken out to form a face panel, three-fourths of it are put back in the form of a pilaster. The object of the panel, as of the 1½ inch to the foot batter which he gives to the wall, is not to save material, for this involves loss of weight and grip on the ground, but to effect a better distribution of pressure on the foundation. It may be mentioned that the whole of the walls on the District railway were designed on this basis, and that there has not been a single instance of settlement,

or of coming over or sliding forward. The author has in the present paper analyzed a few dozen experiments, and discussed as many more facts; but an engineer's experience is the outcome not of a few facts, but of the thousands of incidents which force themselves on his attention in carrying out work, and it is this experience, acquired in the construction of works of a somewhat special character, which has convinced the author that the laws governing the lateral pressure of earthwork are not at present satisfactorily formulated.

ELECTRIC POWER.

From "The Engineer."

Just now nothing save electricity is talked about in scientific circles. During the meeting of the British Association the greatest possible prominence was given to electrical questions and propositions. The success of the electric light, the introduction of the Faure battery with a great flourish of trumpets, and the magnificent display of electrical instruments and machinery at Paris, have all operated to the same end. The daily press has taken the subject up, and journals which were nothing hitherto if not political, now indulge in magnificent rhapsodies concerning the future of electricity. Even eminent engineers carried away by the intoxication of the moment have not hesitated to say that the steam engine is doomed, and that its place will be taken by the electricity engine. In the midst of all this noise and clamor, and blowing of personal trumpets, it is not easy to keep one's head clear, and mistakes may be made which will cause disappointment to many and retard the progress of electrical science. We confidently expect that electricity will prove a potent agent by-and-bye in the hands of the speculator for extracting gold from the pockets of the public, and we write now to warn our readers in time, and to endeavour to clear the air of some of the mists with which it is obscured. There is, no doubt, a great future before electricity; but it is equally certain that electricity can never do many things which the half-informed may be readily made to believe it will do. We propose here to say enough on this point to enlighten our readers without troubling them with perplexing problems and speculations.

No one at this moment knows what electricity is; but for our present purpose we may regard it as a fluid, non-elastic, and without weight, and universally diffused through the universe. To judge by recently-published statements, a large section of the reading public are taught that this fluid is a source of power, and that it may be made to do the work of coal. This is a delusion. So long as electricity remains in what we may call a normal state of repose, it is inert. Before *we can get any work out of electricity a somewhat greater amount of work must be done upon it.* If this fundamental and most important truth be kept in view, it will not be easy to make a grave mistake in estimating the value of any of the numerous schemes for making electricity do work which will ere long be brought before the public. To render our meaning clearer, we may explain that in producing the electric light, for instance, a certain quantity of electricity passes in through one wire to the lamp, and precisely the same quantity passes out through the other wire, and on to the earth or return wire completing the circuit. Not only is the quantity the same, the velocity is also unchanged. But in going through the lamp the current has done something. It has overcome the resistance of carbons, heated them to a dazzling white heat, and so performed work. In doing this, the current of electricity has lost something. Led from the first lamp to a second, it is found powerless—if the first lamp be of sufficient size. What is it that the electricity has lost? It has parted with what electricians term "potential," or the capacity for performing work. What this is precisely, or in what way the presence or absence of potential modifies the nature of the electric current, no one knows; but it is known that this potential can only be conferred on electricity by doing work on the electricity in the first instance. The analogy between electricity and a liquid like water will now be re-

cognized. So long as the water is at rest it is inert. If we pump it up to a height, we confer on it the equivalent of potential. We can let the water fall into the buckets of an overshot wheel. Its velocity leaving the tail race may be identical with that at which it left the supply trough to descend on the wheel. Its quantity will be the same. It will be in all respects unchanged, just as the current of electricity passing through a lamp is unchanged; but it has, nevertheless, lost something. It has parted with its potential—its capacity for doing work—and it becomes once more inert. But the duty which it discharged in turning the mill wheel was somewhat less than the precise equivalent of the work done in pumping it up to a level with the top of the wheel. In the same way the electric current never can do work equal in amount to the work done on it in endowing it with potential.

It will thus be seen that electricity can only be used as a means of transmitting power from one place to another, or for storing power up at one time to be used at a subsequent period; but it cannot be used to originate power in the way coal can be used. It possesses no inherent potential. It is incapable of performing work unless something is done to it first. We have spoken of it as a fluid, but only for sake of illustration. As we have said, no one knows what it is, but the theory which bids fair for acceptance is that it is a mode of motion of the all-pervading ether. Very curious and instructive experiments are now being carried out in Paris by Dr. Bjerkness, of Christiana, in the Norwegian section of the electrical exhibition. This gentleman submerges thin elastic diaphragms in water, and causes them to vibrate, or rather pulsate, by compressed air. He finds that if they pulsate synchronously they attract each other. If the pulsations are not simultaneous, the discs repel each other. From this and other results which he has obtained, it may be argued that the ether plays the part of the water in Dr. Bjerkness' tank, and that when special forms of vibration are set up in bodies they become competent to attract or repel other bodies. This being so, it will be seen that the power of attraction or repulsion of an electrical body depends in the first instance on the motion set up in the body attracted or repulsed, and this motion is, of course, some function of work originally done on the body. We need not pursue this argument further. Among the most scientific investigators of the day it is admitted that the efficiency of electricity as a doer of work, or a producer of action at a distance, must depend for its value on the performance of work in some one way or another on the electricity itself in the first instance. It may be worth while here to dispel a popular delusion. It is held very generally that electricity can be made, as, for instance, by the galvanic battery. There is no reason to believe anything of the kind; but whether it is or is not true that electricity is actually made by the combustion of zinc in a galvanic trough, it is quite certain that this electricity, unless it possesses potential, can do no work, no matter how great its quantity. Of course, it is to be understood that all electric currents possess potential. If they did not their presence would be unknown; but the potential of a current is in all cases the result of work done on electricity, either by the oxidation of zinc, or, in some other way. This is a broad principle, but it is strictly consistent in every respect with the truth. Electricity then is, as we have said, totally different from coal; and it can never become a substitute for it alone. Water power, air power, or what we may, for want of a better phrase, call chemical power, combined with electricity, can be used as a substitute for coal; but electricity cannot of itself be employed to do work. It is true, however, that electricity, on which work has already been done, may be found in nature. Atmospheric electricity, for example, may perhaps yet be utilized. It is by no means inconceivable that the electricity contained in a thunder cloud might be employed to charge a Faure battery; but up to the present no one has contemplated obtaining of power from the clouds, and whether it is or is not practicable to utilize a great natural force in this way does not affect our statement. The use of electricity must be confined to its power of transmitting or storing up energy, and this truth being recognized, it becomes easy to estimate the future prospects of electricity at something like their proper value.

It has been proved to a certain extent that electricity can be used to transmit power to a distance, and that it can be used to store it up. Thus far the man of pure science. The engineer now comes on the stage and asks—Can practical difficulties be got over? Can it be made to pay? In trying to answer these questions we cannot do better than deal with one or two definite proposals which have been recently made. That with which we shall first concern ourselves is that trains should be worked by Faure batteries instead of by steam. It is suggested that each carriage of a train should be provided with a dynamo motor, and that batteries enough should be carried by each to drive the wheels, and so propel the train. Let us see how such a scheme would comply with working conditions. Let us take for example a train fifteen coaches on the Great Northern Railway, running without a stop to Peterborough in one hour and forty minutes. The power required would be about 500 horses indicated. To supply this for 100 minutes, even on the most absurdly favorable hypothesis, no les than 25 tons of Faure batteries would be required. Adding to these the weight of the dynamo motors, and that unavoidably added to the coaches, it will be seen that a weight equal to that of an engine would soon be reached. The only possible saving would be some 28 to 30 tons of tender. In return for this all the passengers would have to change coaches at Peterborough, as the train could not be delayed to replace the expended with fresh batteries. This is out of the question. The Faure batteries must all be carried on one vehicle or engine, which could be changed for another, like a locomotive. Even then no advantage would be gained. As to cost, it is very unlikely that the stationary engines which must be provided to drive the dynamo machines for charging the batteries would be more economical than locomotive engines; and if we allow that the dynamo machine only wasted 10 per cent. of the power of the engine, the Faure batteries 10 per cent of the power of the dynamo machines, and the dynamo motors 10 per cent. of the power of the batteries—all ridiculously favorable assumptions—yet the stationary engines would be handicapped with a difference in net efficiency between themselves and the locomotive—admitting the original efficiency per pound o coal in both to be the same—of some 2 7 per cent., we think we may relegate this scheme to the realms of oblivion. Another idea is that by putting up turbines and dynamo machines the steam engine might be superseded by water power. Now it so happens that if all the water power of England were quadrupled it would not nearly suffice for our wants. It may be found worth while perhaps to construct steam engines close to coal pits and send out power from these engines by wire; but the question will be asked, which is the cheaper of the two, to send the coal or to send the power? On the answer to this will depend the decision of the mill owners. Another favorite scheme is that embodied in the Siemens' electrical railway. We believe that there is a great future in store for electricity as a worker of tramway traffic; but the traffic on a great line like the Midland or Great Northern Railway could not be carried on by it. As Robert Stephenson said of the atmospheric system, it is flexible enough. The working of points and crossings, and the shunting of trains and wagons, would present unsurmountable difficulties. We have cited proposals enough, we think, to illustrate our meaning. Sir William Armstrong, Sir Frederick Bramwell, Dr. Siemens, Sir W. Thompson, and many others may be excused if they are a little enthusiastic. They are just now overjoyed with success attained; but when the time comes for sober reflection they will, no doubt, see good reason to moderate their views. No one can say, of course, what further discoveries may bring to light; but recent speakers and writers have found in what is known already, materials for sketching out a romance of electricity. It is but romancing to assert that the end of the steam engine is at hand. Wonderful and mystical as electricity is, there are some very hard and dry facts about it, and these facts are all opposed to the theory that it can become man's servant of all work. Ariel-like, electricity may put a girdle round the earth in forty minutes; but it shows no great aptitude for superseding the useful old giant steam, who has toiled for the world so long and to such good purpose.

STRENGTH AND DUCTILITY OF THE COPPER-TIN-ZINC ALLOYS.

By ROBERT H. THURSTON.

(Presented at the 13th Annual Convention, June 17th, 1881.)

From the Transactions of the American Society of Civil Engineers.*

I.

In a paper read before the American Society of Civil Engineers a few months since,* the writer gave an account of a method of research which led to the approximate determination of the composition of the strongest possible triple alloy of copper-tin-zinc, and described the properties of alloys made with with more or less accuracy and care by the formula of composition so obtained. In order to exhibit the relation of such metals to the other triple alloys, some of which were already well known compositions, a sketch was given of the relief model used in the identification of the strongest possible metal obtainable by mixture of the three constituents, and a map exhibiting lines of equal tenacity as derived by admeasurements of this model was also introduced as presenting the tenacity of the alloys with greater exactness. This map is here reproduced with some modifications (Fig. 1) which are demanded in further study of the characteristics of these alloys. It was remarked in the earlier paper:

"These alloys were purposely made precisely as the brass founder is accustomed to make them, without other precautions than those observed by every good founder, and without using any of the deoxidizing fluxes—as phosphorus—that would have been experimented with later. The intention was to make this first survey of the field rapidly, inexpensively, and in such a manner as to give a good idea of the best way to pursue the later and much more exact research, while giving the founder a good idea of the nature of the metals that he turns out in every day work.

"The data obtained were consequently exceedingly variable, and the results of this work indicated as one, and not the least valuable, of deductions from it that the same alloy, and especially where the proportion of copper is great, may give very different figures, when tested, according as it is more or less affected by the many circumstances that influence the value of all brass-foundry products.

"Some of the variations in the model are probably due to such accidental circumstances, and quality shown by any individual alloy is representative of a mean which the writer was often compelled to deduce from observations which were quite discrepant. But allowing for all such minor variations, it is evident at a glance that the alloys of maximum strength are grouped, as shown in Figs. 3 and 4, about a point not far from copper=55, zinc=43, tin=2. This point is encircled in the map, Fig. 3, by the line marked 65,000 pounds per square inch (4,570 kilogs. per sq. cm.) tenacity, and is represented on the model by the peak of the mountain seen at the farthest side—the copper zinc side as drawn.

"This is obviously the strongest of all bronzes, and an alloy of this composition, if exactly proportioned, well melted, perfectly fluxed, and so poured as to produce sound and pure metallic alloy, with such prompt cooling as shall prevent liquidation, is the strongest bronze that man can make."

This alloy and the "Tobin alloy"—copper, 58.22; tin, 2.30; zinc, 39.48—were described as good working metals, having toughness and some ductility as well as great strength, and the latter as being capable of great improvement by skillful working either hot or cold, and thus of attaining a tenacity of over 100,000 pounds per square inch (7,311 kilogs. per sq. cm.). Following the inequalities exhibited by the map, the writer called attention to the fact that a line of maximum elevation crosses the field from

* "The Strongest of the Bronzes." Trans. Am. Soc. C. E. No. CCXIV.: Vol. X.; Jan., 1881.

about: copper, 50; zinc, 50; to copper, 85; tin, 15; is included in a band bounded by the formulas: $M=Z+4t=50$, and $M=Z+3t=55$, in which Z is the percentage of zinc present in any triple alloy of that series, and T is the percentage of tin. It was stated that along this maximum line the tenacities of the alloys should be at least $T_m=40{,}000+500z$ in pounds on the square inch, or $T'_m=2{,}812+35.15z$ in kilograms on the square centimeter. Thus taking the last line which contains the strongest but least ductile compositions, we find the following tenacities:

The alloy $z=1$, $t=18$ will also contain copper$=100-19=81$ and this alloy cu. 81, zn. 1, sn. 18 should have a tenacity of at least

$T_m=40{,}000+(500\times1)=40{,}500$ lbs. per sq. in.

$T'_m=2{,}812+(35.15\times1)=2{,}847$ kgs. per sq. cm.

The alloy: cu. 60; zn. 5; sn. 16; should have at least the strength

$T_m=40{,}000+(500\times5)=42{,}500$ lbs. per sq. in.

$T'_m=2{,}812+(35.15\times5)=2{,}988$ kgs. per sq. cm.

while the alloy z, 50; sn. 2; cu, 48; should give, as a minimum per specification:

$T_m=40{,}000+(500\times50)=65{,}000$ lbs. per sq. in.

$T'_m=2{,}815+(35.15\times50)=4{,}570$ kgs. per sq. cm.

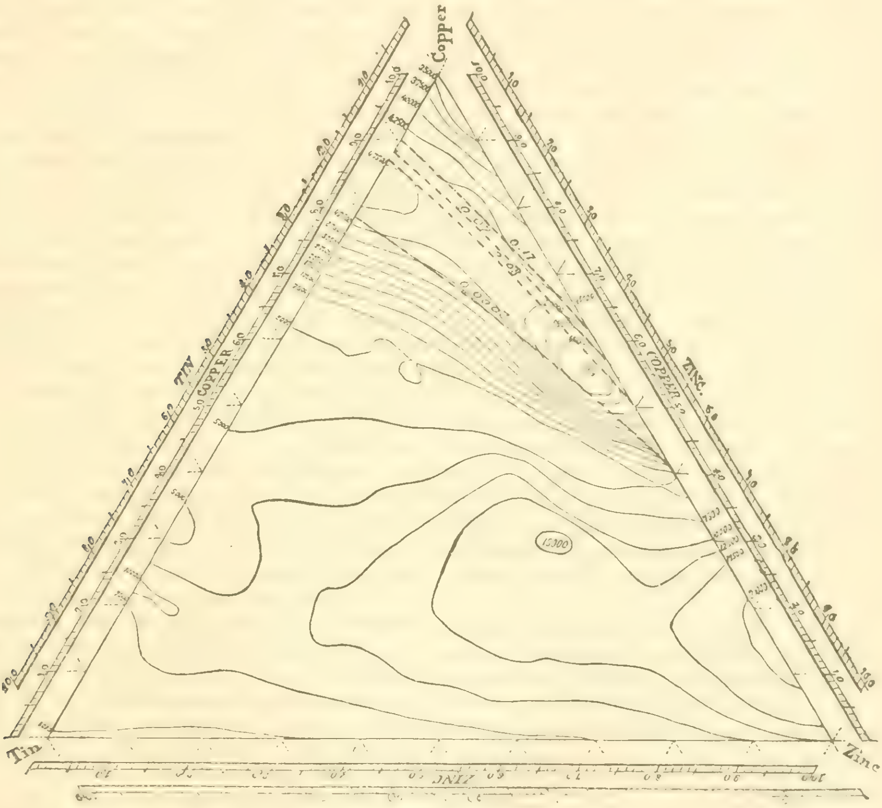


Fig. 1.

"These are rough working formulas that, while often departed from in fact, and while purely empirical, may prove of real value in framing specifications. The formula for the value of T_m fails with alloys containing less than 1 *per cent. tin*, as the strength then rapidly falls to $t=0$."

The writer does not recommend these alloys of maximum tendency for all pur-

poses of construction, as many of them, especially those near the tin sides, are too deficient in ductility and resilience to be safely used where likely to be exposed to severe shock. Where the composition is that of brass, rather than bronze, this line of alloys exhibits more toughness. The alloys—copper, 55; tin, 2; zinc, 43; and copper, 55, tin, 0.5;* zinc, 44.5—were quite excellent in this particular. Tin reduces ductility more rapidly than does zinc. Alloys on the copper side of $z+4t=40$ are all tough metals. The copper tin alloys or bronzes, as was stated, should have a tenacity of at least: $Tt=30,000+1,000t$ where containing not more than 15 per cent. tin, or in metric measure, $T^{\prime}t=2,109+70.3t$, while the brasses or copper-zinc alloys up to 50 per cent. zinc should have a strength, in British and metric units respectively, of $T^{z}=30,000+500z$ and $T^{\prime}{}_{z}=2,109+35.15z$. Thus gun bronze can be given about $30,000+(1,000\times 10)=40,000$ lbs. per square inch if well made. In metric measures, $2,109+703=2,812$ kilogs. per sq. cm. Copper, 70; zinc, 30, should have a tenacity of $30,000+(500\times 30)=45,000$ lbs. on the square inch, or $2,109+(35.15\times 30)=3,165$ kilogs. per square centimeter. Comparing the last two formulas for tenacity, it is seen that they may be combined, giving equations covering the whole field of copper-tin-zinc alloys useful to the engineer, thus:

$$T_{zt}=30,000+1,000t+500z.$$
$$T_{zt}=2,109+70.3t+35.15z.$$

But it must be understood that this approximate statement of tenacities is a minimum for well-made alloys, and is also applicable only to those containing a larger per centage of copper than those which lie along the maximum line; the alloys to which they apply are, however, the best alloys for general use. Like all such formulations, they must be taken with reserve, and as only representing the cases from the study of which they were derived. For all ordinary purposes of the engineer they may be used without hesitation. Thus we get, for alloys in which $z+4t<40$, the following tenacities, representing the minimum that should be accepted. These figures may be greatly exceeded:

* Not 2.5 as printed in earlier paper.

Alloy. Cu.	Zn.	Sn.	Tenacity—Probable Minimum. Lbs. per sq. in.	Kgs. per sq. cm.
100	0	0	30 000	2 109
95	5	0	32 500	2 285
90	10	0	35 000	2 460
85	15	0	37 500	2 636
90	0	10	40 000	2 812
95	0	5	35 000	2 460
97½	0	2½	32 500	2 285
90	5	5	37 500	2 636
85	10	5	40 000	2 812
75	20	5	45 000	3 163
68	30	2	47 000	3 304
64	35	1	48 500	3 410
60	40	0	50 000	3 515

The ductility of these alloys is a subject of quite as much interest to the engineer as their strength; and in this quality the triple alloys are as variable as in every other. Referring again to the map, Fig. 1, it is seen that a closely grouped set of slightly curved and slowly converging lines cross it from about tin $=25$ to zinc $=55$, the mean line having an equation, nearly $2.2t+z=55$. Along this line the alloys have an immense tenacity as exhibited by the fact that some of them, if not nearly all, too hard to be cut by steel tools, and in shaping them only grinding tools—either the emery wheel or grindstone—could be used, and even then with the most unsatisfactory results. Yet such was the brittleness of these metals that no reliable test of their strength could be obtained. Even the slow and cautious handling possible in the autographic machine was quite inadequate to the production of regular and satisfactory determinations. The strain diagrams obtained were perfectly straight, and nearly vertical lines terminating suddenly when the piece snapped without the slightest indication of approach to an elastic limit. They were apparently perfectly elastic up to the point of fracture, but were so nearly destitute of resilience that no use can probably be made of them. Their brittleness was such that they would often break in the mould by their own contraction in cooling, although cast in a straight bar one inch (2.5 c.m.) thick and less than 30 inches (75 c.m.) long. In some cases they were cracked by the heat of the hand, and in several instances were broken at the end by the jar transmitted from a light blow struck at the other end.*

The border lines of this valueless ter-

* Report of United States Board.

ritory is shown on the map by a slightly curved dotted line to which a line having the equation $2.5t+z=55$ is nearly tangent. The alloys lying along this line have nearly equal ductility, extending according to the measurements obtained by the autographic machine, about .03 of one per cent.

Above this line is seen another having nearly the equation $4t+z=50$, which last line is that of equal ductility for alloys exhibiting extensions on the strain diagram of 3 per cent. Still nearer the "pure copper corner" fairly representing alloys containing about $3\frac{3}{4}t+z=48$, and along which the extensions, as per strain diagrams were 7.3 per cent., and another such line extending from the standard gun-metal compositions on the one side to the tough Muntz metal on the other —cu. 90; sn. 10: to cu. 55; zn. 45—of which the equation is nearly $4.5t+z=45$, represents and identifies alloys averaging as cast during this initial research, an extension of 17 per cent. These lines are best seen on the sheet of extensions, Fig. 25. All alloys lying above the line taken here as a boundary line give figures for tenacity that are usually considered good; they all exceed 30,000 pounds per square inch (2,109 kilogs. per sq. cm.).

It is seen that the addition of tin and of zinc to cast copper increases tenacity at least up to a limit marked by the line $3t+z=55$, and that the influence of tin is nearly twice as great as that of zinc, while the limit of useful effect is not reached in the latter case until the amount added becomes very much greater than with the former class—the copper tin alloys.

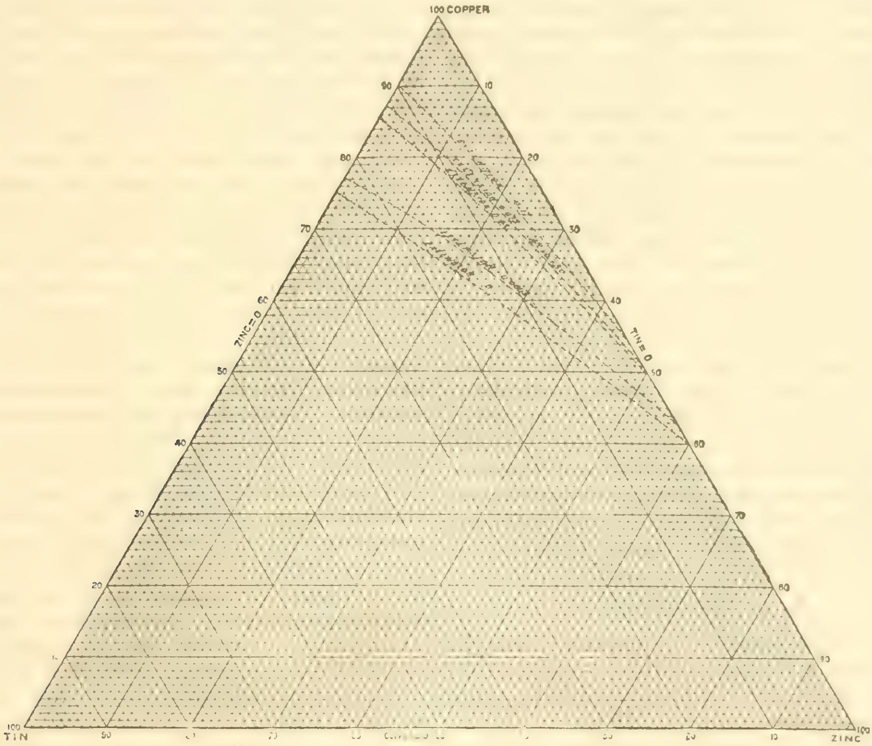


Fig. 2.

Brasses can be obtained which are stronger than any bronzes, and the ductility of the working compositions of the former class generally greatly exceeds that of the latter.

Triple alloys may be made containing about $4t+z=50$, which exceed in strength any of the double alloys and composi-

tions approaching copper, 55 tin, 2 ; zinc, 43 ; as the maximum of maximums, may be made, which are of extraordinary value for purposes demanding great strength, combined with the peculiar advantages offered by brass or bronze. The addition of one-half per cent. tin to Muntz metal confers vastly increased strength. So sensitive is zinc in the presence of tin that M. Bischof states that he can detect the addition of one part of tin in ten millions of pure zinc.

The range of useful introduction of tin is very much more restricted than with zinc ; alloys containing 12 to 15 per per cent. are so hard and brittle as to but rarely find application in the arts, while brass, containing 40 per cent. zinc, is about the toughest and most generally useful of all the copper-zinc "mixtures." The moduli of elasticity of these alloys are remarkably uniform, more than one-half of all those here described, ranging closely up to fourteen millions, or one-half that of well-made steel wire, such as is used in the New York and Brooklyn Bridge. The moduli gradually and slowly increase from the beginning of the test to the elastic limit.

The fracture of these alloys is always illustrative of their special characteristics. Those broken by tortion in the autographic testing machine were, if brittle, more or less conoidal at one side of the break ; ductile alloys yield in similar circumstances by shearing in a plane at right angles to the axis of the test piece ; the former resemble cast iron and the latter have the fracture of wrought iron. Every shade of gradation in this respect is exhibited by an observable modification of the surface of fracture, varying from that characteristic of extreme rigidity and brittleness, through an interesting variety of intermediate and compound forms to that seen in fracture of the most ductile metals.

Notwithstanding the fact that the demise of the United States Board left this investigation in a sadly incomplete state, it will probably become evident to those who may obtain the report that at least a beginning has been made and the field fairly reconnoitered,leaving to some future investigator a prospect of immediate valuable recompense for such additionable labor as he may be able to expend in a detailed reconnoissance or an extended survey. While studying the figures here given, and especially those reported by the United States Board, it must not be forgotten that the tenacities and even the ductilities given are far within the best attainable figures where they relate to the most valuable working bronzes and brasses. These figures represent the result of ordinary, every day founders' work, and metals rich in copper made, as were these, with no greater precaution against oxidation and liquidation than is usual in brass foundries, may be vastly improved by the special treatment suggested in the preceding paper, by using pure ingot metals, fluxing carefully, as with phosphorus or manganese, casting in chills, rapid cooling, and finally rolling or otherwise compressing either hot or cold.

Unannealed copper wire is reported by Baudrimont* as having a tenacity of about 45,000 pounds per square inch (3,163 kilogs. per sq. c. m.), and Kirkaldy reports 28.2 tons per square inch (63,168 pounds per square inch; 4,440 kilogs. per square c. m.), the wires having diameters of 0.0177 and 0.064 inches (0.044 and 0.165 c, m.) respectively.

It can hardly be doubted that a way may yet be found to secure equal purity, homogeneousness, and density in cast copper, and such metal should then possess equal tenacity and toughness with rolled metal. Gun-bronze, which ordinarily has a tenacity of about 35,000 pounds per square inch (2,460 kilogs. per sq. c. m.) has been made at the Washington Navy Yard, by skillful mixture, melting and pouring, to attain a tenacity of above 60,000 pounds (4,218 kilogs.).

The effect of thorough fluxing with deoxidizing substances is so important that no founder can safely neglect it.

Bronzes fluxed with phosphorus, arsenic, and manganese have been given fifty per cent. higher tenacity than the ordinary unfluxed alloy, and the addition of a little iron, as in the so-called "sterro-metal" of the Baron de Rosthorn, and in Parson's "Manganese Bronze," has still further strengthened the copper-tin-zinc alloys.

Attention has been called in the preceding paper to the value of gold rolling, and other mechanical treatment of the

* Annales de Chimie, 1850.

"maximum alloys," examined by the writer, and one case was cited in which the tenacity was increased from 66,500 pounds per square inch (4,575 kilogs. per sq. c. m.) by rolling hot to 79,000 pounds (5,553 kilogs.), and by cold rolling to 104,000 pounds (7,311 kilogs.). Dr. Anderson, the Superintendent of Machinery of the British War Department, when associated with the writer at Vienna, 1873, referred to experiments at Woolwich, showing an increase of strength of sterro-metal by forging to the extent of 25 per cent,, and by drawing cold of 40 per cent. Brass, containing copper, 62 to 70; zinc, 38 to 30, attains a strength in the wire mill of 90,000 pounds per square inch, and sometimes of 100,000 (6,327 to 7,030 kilogs. per sq. c.m.), and the time will come, we may hope, and fairly expect, when these alloys may be made equally tenacious in the casting. The writer has no doubt that the methods indicated by him as those best adapted to secure dense, strong and tough metal will yet be found capable of yielding ailoys, of more than double the strength shown here to be fairly representative of what is now ordinary brass founder's work. It should be possible to secure copper-tin-zinc alloys having tenacities represented by:

$$T_{mm} = 60{,}000t + 1{,}000t + 500$$
$$T_{1\,mm} = 4{,}218 + 70.3t + 35.15_z,$$

throughout that area on the map representing the more useful alloys, say from copper, 100; to $4t+z=50$.

Manufacturers of special bronzes are already approaching this degree of excellence. The appended tables illustrate the method of investigation adopted in studying the triple alloys, and exhibit the behavior under test of the sample of "Gun Bronze, No. 1,252," of which autographic strain diagrams were given in the preceding paper on "The strongest of Bronzes." This bar was made to order for the writer to determine the value of an organic material proposed as a flux; it had no special value, however, and the record is here given in illustration only.

No. 585 was a sample of brass in which 20 per cent. zinc, takes the place of 10 per. cent. tin in bar No. 1,252. This piece had very nearly the same tenacity, double the ductility, a slightly lower modulus of elasticity, and far less transverse strength—probably in consequence of less hardness. Adding zinc until the proportion becomes 37.5 per cent., as in No. 609, the tenacity rises to 48,760 pounds per square inch (3,428 kilogs. per sq. c.m.), the modulus of elasticity is increased to fifteen millions, and the transverse strength is doubled.

No. 856 is an alloy of very nearly the same composition, to which 23 per cent. tin has been added. It is seen that this change has produced an enormous increase of strength, bringing the tenacity up to 67,600 pounds per square inch (4,752 kilogs. per sq. c.m.), and while decreasing the modulus of elasticity has greatly increased the transverse strength. This bar was referred to in the preceding paper, and the records of its test are here also appended as exhibiting the behavior of this alloy during the progress of the tests. The extensions given are measured in a length of five inches; they are, therefore, to be multiplied by 20 to obtain the per centage of extension. This bar is very strong, but deficient in ductility.

The transverse tests exhibits these characteristics with equal distinctness. The load carried was nearly a ton and a half, and the deflection but 2 inches (5 c. m.); the modulus of elasticity slowly but steadily decreased from the start. Note (*a*) calls attention to a phenomenon more than once noticed, of an increased effort to decrease flexure after a short interval of rest under light load, having received set under heavier stress. The remainder of the record illustrates the usual gradual increase of set under heavy loads. Somewhat similar behavior was noticed in the transverse test of No. 1,001, an alloy of which the strain diagrams from the autographic machine were given in the paper on the strongest of the bronzes. The note appended to the record calls attention to the singular recovery from set, which here amounts to 0.004 inches (0.01 cm.) in about 16 hours.

The last set of records here given are those of a pure bar copper, made and tested for the U. S. Board,* and show well what may be expected of good copper castings, even without special fluxing

* See Report of 1878.

or other unusual treatment. This bar was strong, carrying nearly 30,000 pounds per square inch (21.09 kilogs. per sq. cm.) in tension, but it lacked ductility, a consequence of the presence of copper oxide.

In the working of copper in the foundry the melter is sure to meet with difficulty from the formation of either the oxide or carbide. Could he secure immunity from the danger of combination with one or the other of these elements, he would find innumerable uses for cast copper. One of the discoveries to be looked for, and to be hoped for, is a method of securing pure cast copper. The stronger affinities of the metal, when molten, make this problem a more difficult one than that of obtaining sound steel castings. The transverse strength of the metal seemed to have been less reduced by the presence of the oxide than was its tenacity. The fact that the bar could be broken at all in the transverse testing machine is evidence of reduction of ductility due to this cause. The record of the compression test seems to indicate that form of resistance due to the presence of oxide.

The general character and the method of variation of strength and ducility of the alloys of copper, tin, and zinc are so well exhibited by the illustrations which have been presented in these papers, that it is the hope of the writer that no difficulty will be met with by the engineer in the endeavor to select the alloy best adapted to any specific purpose where such an adaptation is determined by physical qualities alone. Caution must be used in selecting alloys where great strength is demanded, since a slight change of composition by the addition of tin or zinc may make a serious change in the direction of lessened ductility and toughness. The engineer will rarely use those lying on the tin and zinc side of the line of alloys having 0.07 (7 per cent.) ductility, as on Figs. 1 and 2. Extraordinary care must also be taken in making the strongest of these alloys.

Alloys to be hammered or rolled will be found more difficult to work as the per centage of tin is increased, and the minutest addition of tin to the brasses usually rolled is found to sensibly decrease their manageability.

RECORDS OF TESTS MADE AT THE STEVENS INSTITUTE OF TECHNOLOGY.

Material Bronze—Copper, 89,974 per cent.; Tin, 9,997 per cent.; Flux, etc., 0,029 per cent.

I. RECORD ACCOMPANYING AUTOGRAPHIC STRAIN DIAGRAMS.

GUN BRONZE.

Lab. No.	Size for Estimates. Length L	Size for Estimates. Diameter H	Stresses in Torsion. foot-pounds. Proof M'	Stresses in Torsion. foot-pounds. Ultimate M	Elasticity.	Elasticity Resilience.	Ratio of Extension. Proof.	Ratio of Extension. Maximum.	Homogeneousness as to Structure.	Homogeneousness as to Strain.	Stiffness.	Resilience W	Modulus of Resistance Torsion (A) Elastic. $A_E = \frac{M'L}{H^5 \theta_E}$	Modulus of Resistance Torsion (A) Proof $A' = \frac{M'}{H^3}$	Modulus of Resistance Torsion (A) Ultimate $A = \frac{M}{H^3}$	Angle. θ_E	Angle. θ_R
1252B	1″	.625″	49.03	99.83	.00717	0.38	.000013	.04737	Ex.	Ex.	54.5	84.60	571.2	200.94	409.1	0.9°	57.2
$1252B_2$	"	"	71.71	127.05	.00776	1.55	.000089	.07554	"	"	29.9	138.66	313.3	293.9	520.7	2.4°	72.6

2. Records of Tests by Tension.

Copper....89.974%

Tin....... 9.997% GUN BRONZE.

Flux, etc.. 0.029% Lab. No. 1252A²

Dimensions Original and Final.		Stresses.		Proof Load per Square Inch Area of	Breaking Load per Square Inch.	Extension.		Modulus of Elasticity. E	Modulus of Resilience. W
Length. L, L′	Diameter. H, H′	Proof.	Ultimate.	Original Section P	Original Section T	Actual	% of Original Length.		
5″	.798″	150	....	300	....	......	......	11 467 763	
....	....	1000	....	2000	....	.0008	.016%		
....	....	2000	....	4000	....	.0016	.03		
....	....	3000	....	6000	....	.0024	.05		
....	....	4000	....	8000	....	.0036	.07		
Elastic	Limit.	5000	....	10000	....	.0047	.09	....	0.98
....	....	6000	....	12000	....	.0063	.13		
....	....	7000	....	14000	....	.0080	.16		
....	....	8000	....	16000	....	.0112	.22		
....	....	9000	....	18000	....	.0166	.33		
....	....	10000	....	20000	....	.0263	0.53		
....	....	11000	....	22000	....	.0428	.86		
....	....	12000	....	24000	....	.0675	1.35		
....	....	13000	....	26000	....	.1009	2.045		
....	....	15000	....	30000	....	.2069	4.14		
....	....	....	15500	....	31000	.23	4.6	....	242

3. Records of Tests by Compression.

Copper.... 89.974%

Tin........ 9.997% GUN BRONZE.

Flux, &c.. 0 029% Lab. No. 1252C_2.

Dimensions. Original and Final.		Stresses.	Proof load per square inch area of	Breaking load per square inch.	Compression.		Resilience. W
Length. L,L′	Diameter H,H′	Proof.	Original section. P.	Original section. T.	Actual.	Per ct. of original length.	Foot. Pounds
2″	.625	150	....	....	....	....	
....	....	1000	....	....	0.0019″	0.09%	
....	....	2000	....	....	.0032	.16	
....	....	3000	....	....	.0033	.16	
....	....	4000	....	....	.0040	.20	
....	....	5000	....	....	.0048	.24	
....	....	6000	....	....	.0076	.38	
Elastic limit.		7000	22816	....	.0117	.58	6.825
....	....	8000	....	....	.0227	1.13	
....	....	9000	....	....	.0385	1.92	
....	....	10000	....	....	.0609	3.04	
....	....	11000	....	....	.0867	4.33	
....	....	12000	....	....	.1163	5 81	
....	....	13000	....	....	.1494	7.47	
....	....	14000	....	....	.1794	8.97	
....	....	15000	....	....	.2110	10.55	
....	....	16000	....	....	.2402	12.01	
....	....	17000	....	....	.2678	13.39	
....	....	18000	....	....	.2989	14.94	
....	....	19000	....	....	.3229	16.14	
....	....	20000	....	....	.03599	17.99	
....	....	21000	....	....	.3904	19.52	
....	....	22000	....	....	.4164	20.82	
....	....	23000	....	....	.4478	22.39	
....	....	24000	....	....	.4870	24.35	
....	....	25000	....	....	.5092	25.46	
....	....	26000	....	....	.5409	27.04	
....	....	27000	....	....	.5706	28.53	
....	....	28000	....	....	.5999	29.99	
....	....	29000	....	....	.6235	31.17	
....	....	30000	....	....	.6460	32.30	
....	....	31000	....	....	.6694	33.47	
....	....	32000	....	....	.6904	34.52	
....	....	33000	....	....	.7125	35.62	
....	....	34000	....	....	.7311	36.55	
....	....	35000	....	....	.7517	37.58	
....	....	36000	....	....	.7726	38.63	
....	....	37000	....	....	.7914	39.57	
....	.769	38000	....	123860	.8115	40.57	1.480

4. RECORDS OF TESTS BY TRANSVERSE STRESS.

		Dimensions Original and Final.		
		Length.	Breadth.	Depth.
Copper.... 89.974% Tin....... 9.997% Flux, &c... 0.029%	GUN BRONZE. Lab. No. 1252.	l. l'.	b. b'.	d. d'.
		22"	1.020"	0.97"

	Proof stresses. Absolute. P_1	Proof stresses. Modulus. $R_1=\frac{3P_1l}{2bd_2}$	Deflection. Absolute. δ	Breaking load. Absolute. P	Breaking load. Modulus. $R=\frac{3Pl}{2bd_2}$	Modulus of elasticity. $E=\frac{Pl_3}{48\delta 1}$	Modulus of resilience. W Ft. lbs.
	3	....	....	....	....	....	
	10	....	0.0016"			13,487,264	
	20	....	.0036				
	40	....	.0084				
	80	....	.0179				
	120	....	.0257				
	160	....	.0344				
	200	....	.0429				
	3	....	.0012				
	240	....	.0502				
	280	....	.0581				
	320	....	.0669				
	360	....	.0761				
	400	....	.0845				
	3	....	.0034				
	440	....	.0929				
	480	....	.1015				
	520	....	.1102				
	560	....	.1192				
	600	....	.1277				
	3	....	0.0054				
	640	....	.1364				
Elastic limit.	680	23,375	.1463	....	....	....	4.145
	720	....	.1594				
	760	....	.1717				
	800	....	.1879				
	3	....	.0276				
	840	....	.2039				
	880	....	.2219				
	920	....	.2475				
	960	....	.2832				
	1000	....	.3310				
	3	....	.1248				
	1040	....	.3841				
	1080	....	.4426				
	1120	....	.5359				
	1160	....	.6492				
	1200	....	.7774				
	3	....	.5114				
	1240	....	.9043				
	1280	....	1.027				
	1320	....	1.1998				
	1360	....	1.407				
	1400	....	1.694				
	3	....	1.2008				
	1440	....	1.835				
	1480	....	2.020				
	1520	....	2.237				
	1560	....	2.553				
	1600	....	3.1108				
	3	....	2.462				
	1640	....	3.358	1640	56,375	....	327,5

EXPERIMENTS ON THE OTTO GAS ENGINE.

By Prof. FRANCESCO SINIGAGLIA.

From "L'Ingegneria civile e le Arti Industriali" for Abstracts of Institution of Civil Engineers.

This paper consists in a mathematical investigation of a large number of indicator diagrams, sixteen of which are reproduced for reference. The diagrams are of two kinds; the first refer to the results obtained from the explosion of the mixture of gas and ordinary air, which may be called diagrams of motor power; the second kind are obtained when the valve which admits the gas is closed, and are called diagrams of resistance. The various stages of pressure are clearly represented by the diagrams, from which it appears that at the end of the motor stroke the internal pressure in the cylinder is less than that of the atmosphere. The highest pressure figured on any of the diagrams is 7 atmospheres. The author remarks that the machine is liable to become dirty internally; and should be frequently overhauled and cleaned. The editor of the journal adds in a note, that if oil of a good quality is employed for lubrication it is sufficient for the valve to be cleaned every twelve or fifteen days, and the interior of the cylinder once a month. From a great number of diagrams the author deduces the following formulæ:—

Let A = the area of piston in square centimeters, which = 103.81.

C = the length of stroke in meters, which = 0.2315.

p_m = the mean pressure, taken from the diagrams.

n = the number of strokes per second.

Then the work is thus represented:

$$\frac{np_m AC}{2\times 60} \text{ kilogrammeters per second.}$$

The author proceeds to give formulæ, too complicated for abstract, for the resistance of the machines, for proportion between the gas consumed and the air admitted, for the heat produced by the combustion, for the heat conducted away by the products of combustion, for the relation between these two last-mentioned quantities, for the relation between the heat developed and that absorbed by the water, for the heat lost by vaporization of water and by radiation, and for the proportion between the work indicated by the diagrams, and that actually utilized as motor power. He finally arrives at the result that the indicated work, where $n=170$, and $p_m=1.590$, amounts to 0.722 HP.; the friction to 0.283 HP.; and the effective work to 0.439 HP., or 60 per cent. of useful effect.

The consumption of gas per HP. indicated per hour he gives as,

$$\frac{0.960 \text{ cubic meter}}{0.734 \text{ HP}} = 1.307 \text{ cubic meter,}$$

and per HP. effective as

$$\frac{0.960 \text{ cubic meter}}{0.451 \text{ HP.}} = 2.128 \text{ cubic meters.}$$

The editor adds a note to the effect that a consumption of 1.200 cubic meters per HP. per hour is the highest that has yet been determined from numerous experiments conducted by very able engineers for any of these engines.

The author concludes that the diagrams derived from his practice differ from those drawn according to theory, those drawn according to Boyle's law of compression being 20 per cent. in excess of, and those drawn according to the adiabatic theory being 20 per cent. less than those which he has obtained. The cost of gas, at the price of 32 centissimi per cubic meter (without allowing anything for the hire of meter) is 3.60 lire (2*s.* 10½*d.*) for a day of ten hours, which he states to be much higher than that of a steam engine of equal power, that is to say, of 0.451 effective HP.

A COMPOUND INTEREST CURVE.

By FRANK D. Y. CARPENTER, C.E.

Contributed to Van Nostrand's Engineering Magazine.

All interest is the result of growth. If this growth is uniform, the increase during any period of time being a constant percentage of some fixed capital, the result is simple interest. If it is constantly increasing in rapidity, its amount during any differential of time being a constant percentage of the accumulated principal and increment at the beginning of this period, the result is compound interest.

As far as organic growth can be said to obey any regular law, a human being or a tree increases in stature by simple interest, but in girth by compound interest, since the layer of fiber or tissue added to the trunk, during any interval, must be sufficient to inclose all preceding envelopes, and therefore be larger than the largest of them. The depth of snow during a storm increases by simple interest; the size of a ball of the same rolled along the ground by the school-boy, or dashing down the mountain side until it becomes an avalanche, grows by compound interest. Supposing the nations of the world to remain in a normal condition as regards health, peace, government and prosperity, and our supply of vacant land to continue unstinted, our population will increase through immigration by simple interest, and through reproduction by compound interest.

This and any other growth may be represented graphically by the line which would be described by the culminating point of the growing substance and referred to rectangular axes of co-ordinates. That component of its progress which lies along the axis of abscissas will be a measure of the time considered, while the intercepted portion of the axis of ordinates will represent the amount of principal and interest at any given date. Thus time and matter are given in terms of the same linear measurement. By assigning to them arbitrary values at will, such as one year to the inch for one axis, and a thousand dollars, or one hundred feet, or one million people to the inch for the other, the equation for the line of growth by simple interest takes the form of

$$y = ax + b,$$

of which b is the principal and ax is the accumulated interest. But the above is the equation of the straight line, which is, therefore, the representative of growth by simple interest, a fact which is self-evident when we consider that in this process equal increments to x, the time, are always accompanied by equal increments to y, the amount. To draw this line it is only necessary to find two points in the same—that is, the amount of principal and interest at any two dates, and they will determine its position.

In all of the practical operations into which the computation of compound interest enters, the interest is compounded with the principal at stated intervals, the same rate of interest being applied to the increased principal at the end of each of these periods of time. Thus for equal increments to x, the time, there are constantly increasing increments to y, the amount, and the course of the culminating point is a broken line, of which the sections make larger and larger angles with the axis of abscissas as the time increases. In order to draw this broken line it is necessary to compute the ordinate, that is, the amount, as often as the interest is compounded with the principal, which, in financial transactions, may be annually, semi-annually or quarterly.

Natural growth, however, does not proceed in this broken and angular manner. In natural growth the interest is compounded and a new principal is assumed at the end of each infinitesimal of time, and the broken line melts into a curve. To complete all of the ordinates of this line, as of any other curve, would be literally an infinite work. Therefore, to describe this curve of growth, or compound-interest curve, we first find a convenient number of points lying therein, and through them trace the approximate course of the line desired.

But as natural growth does not proceed in compliance with the terms of any human contract, and we have no means of knowing in advance what will be its rate of increase for each year, day, minute or infinitesimal of time, and what will be the successive values of the growing quantity at the expiration of these periods, we can only treat this subject retrospectively, and interpolate between two values of the growing substance as found by measurement at the beginning and end of a completed cycle of time. To effect this interpolation it has usually been the custom to assume that successive values have constituted a series of which the second differences were equal and the third differences were, therefore, zero; but this is never true for any growth by compound interest, in which, however continued, no order of differences will disappear. It is now desired to find some method of interpolation which will give correct results, assuming that the growth has been in conformity with some regular law of compound interest, this being the only theory admissible.

Let B = the first principal, the measured value at the beginning of the cycle.

Let A = the final amount, the measured value at the end of the cycle considered.

Let n = the number of equal periods into which the cycle is divided, at the end of each of which the interest is compounded with the principal.

Let p = the number of these periods, at the end of which it is desired to find the amount.

Let y = the desired amount.

Let x = the rate per cent. of gain for each period considered.

As in each of these periods the principal, as it was at the beginning of this interval, is increased by a certain fraction of itself, we have the following continued proportion: the first principal is to the second or first amount, as this second is to the third, as the third is to the fourth, etc. That is,

$$\mathrm{B} : \mathrm{B}+\frac{x}{100}\mathrm{B} :: \mathrm{B}\left(1+\frac{x}{100}\right) : \mathrm{B}\left(1+\frac{x}{100}\right)^2 ::$$

$$\cdots\cdots\cdots\cdots$$

$$:: \mathrm{B}\left(1+\frac{x}{100}\right)^{n-1} : \mathrm{B}\left(1+\frac{x}{100}\right)^n$$

But $$\mathrm{B}\left(1+\frac{x}{100}\right)^n=\mathrm{A}$$

whence $$\left(1+\frac{x}{100}\right)^n=\frac{\mathrm{A}}{\mathrm{B}}$$

and $$1+\frac{x}{100}=\left(\frac{\mathrm{A}}{\mathrm{B}}\right)^{\frac{1}{n}} \quad . \quad . \quad . \quad (1)$$

In the same manner it may be demonstrated that

$$\mathrm{B}\left(1+\frac{x}{100}\right)^p=y,$$

$$\left(1+\frac{x}{100}\right)^p=\frac{y}{\mathrm{B}},$$

and $$1+\frac{x}{100}=\left(\frac{y}{\mathrm{B}}\right)^{\frac{1}{p}}.$$

Therefore,

$$\left(\frac{y}{\mathrm{B}}\right)^{\frac{1}{p}}=\left(\frac{\mathrm{A}}{\mathrm{B}}\right)^{\frac{1}{n}},$$

$$\frac{y}{\mathrm{B}}=\left(\frac{\mathrm{A}}{\mathrm{B}}\right)^{\frac{p}{n}},$$

$$\log.\left(\frac{y}{\mathrm{B}}\right)=\frac{p}{n}\cdot\log.\left(\frac{\mathrm{A}}{\mathrm{B}}\right)$$

$$\log. y-\log. \mathrm{B}=\frac{p}{n}\cdot\log.\left(\frac{\mathrm{A}}{\mathrm{B}}\right)$$

$$\log. y=\log. \mathrm{B}+\frac{p}{n}\cdot\log.\left(\frac{\mathrm{A}}{\mathrm{B}}\right) \quad . \quad . \quad (2)$$

Whence y is readily found.

A convenient subject to which to apply this formula is the increase of the population of the United States for the cycle of ten years between the census of 1870 and that of 1880. To avoid too great complication in the problem it will be necessary to neglect the irregularity of increase resulting from varying immigration and other abnormal influences, and to assume that our gain in numbers has been a steady growth by compound interest.

The population of the United States, June 1, 1870, was 38,558,371; on June 1, 1880, 50,152,866; increase, 11,594,495. Theoretically there have been 11,594,495 equal increments to the population, added at intervals of a little less than half a minute, but which intervals have been constantly growing smaller as the population has increased. The interest has been compounded with the principal 11,594,495 times, and the line of growth, being broken by so great a number of sections and angles, is practically a curve and will be treated as such. Since it is manifestly impossible to compute the total 11,594,595 ordinates which deter-

mine the position of this broken line, a smaller number will have to suffice. Let us derive the values of the ordinates of the intervening curve of growth for each year of the decade between 1870 and 1880. Then, the curve having been described with their aid, any intermediate value of the ordinate may be taken directly from the drawing by erecting a perpendicular at that point of the axis of abscissas corresponding to any desired date in the decade. Or the value of this ordinate, or population, may be computed more accurately, as will hereafter be illustrated.

To find, then, for example, the population of the United States, June 1, 1873:

Here B=38,558,371, the initial population of the cycle.

A=50,152,866, the final population.

n=10, the number of equal periods into which the cycle is divided.

p=3, the number of these periods embraced.

Supplying these values in equation (2), we have

$$\log. y = 7.6203718,$$
$$y = 41,722,640.$$

In this manner the following table has been prepared, showing the theoretical increase of the population of the United States from June 1, 1870, to June 1, 1880:

Date.	Population.	Remarks.
June 1, 1870....	38,558,371	Enumerated.
" 1, 1871....	39,585,530	Computed.
" 1, 1872....	40,640,040	"
" 1, 1873....	41,722,640	"
" 1, 1874....	42,834,090	"
" 1, 1875.....	43,975 140	"
" 1, 1876....	45,146,580	"
" 1, 1877....	46,349,240	"
" 1, 1878....	47,583,930	"
" 1, 1879....	48,851,510	"
" 1, 1880....	50,152,866	Enumerated.

To find, by the formula, the population for the intermediate date of April 1, 1873:

A=50,152,866,
B=38,558,371,

n=120, the number of months in the cycle of ten years.

p=34, the number of months from June 1, 1870, to April 1, 1873.

Whence y=41,540,220.

To find the population for the intermediate date of July 4, 1876:

A=50,152,866,
B=38,558,371.

n=3653, the number of days in the cycle of ten years.

p=2226, the number of days from June 1, 1870, to July 4, 1876.

Whence y=45,257,830.

By the aid of this formula the statistician, with the necessary time and inclination, can construct a curved line which will represent the growth of our population from the date of the first census in 1790, to the last in 1880. The enumerated values for the several decades will furnish ordinates which the curve of growth must imperatively touch. Between these positive values the formula will give intermediate ordinates which will locate the intervening theoretical curve of increase. This ideal curve may then be used as a guide line, in the neighborhood of which the historian, having in view the vicissitudes which have influenced the growth of population, may draw an approximately true line of increase. For instance, this curve will not depart widely from the horizontal during the period of our civil war, when death almost kept pace with birth; it will receive an upward impulse in those years in which our immigration is greatest, and also in the spring-time of each year, owing to the excessive influx of immigrants at that time; and it will ascend less rapidly than the normal curve in those seasons in which mortality is greatest, and especially in those years when we have been visited by pestilence. In short, it will be the barometric curve of the nation's prosperity.

The decennial rate of increase of our population for the last decade has been $30\frac{6998}{100.000}$ per cent.

From equation (1),

$$1+\frac{x}{100}=\left(\frac{A}{B}\right)^{\frac{1}{n}},$$

and its sequel,

$$\log.\left(1+\frac{x}{100}\right)=\frac{1}{n}.\log.\left(\frac{A}{B}\right),$$

we derive the annual rate of increase, x, which is $2\frac{66388}{100000}$ or about $2\frac{2}{3}$ per cent.

If any one wishes to indulge in the precarious pastime of guessing at the future, and if he is satisfied to predict a corre-

sponding rate of interest for the present decade, he will find the annual series to run as follows:

Date.	Population.	Remarks.
June 1, 1880....	50,152,866	Enumerated.
" 1, 1881....	51,488,880	Computed.
" 1, 1882....	52,860,480	"
" 1, 1883....	54,268,630	"
" 1, 1884....	55,714,280	"
" 1, 1885....	57,198,450	"
" 1, 1886....	58,722,150	"
" 1, 1887....	60,286,440	"
" 1, 1888....	61,892,400	"
" 1, 1889....	63,541,160	"
" 1, 1890....	65,233,820	"

This forecasting of the population, however, does not rise above the dignity of scientific fortune-telling, and it rarely fails to bring the fortune-teller to grief. Instead of an increase of but 30 per cent. in this decade, the present tide of prosperity may continue and carry us forward $35\frac{6}{10}$ per cent., as in the ten years from 1850 to 1860, and give us a total of 68,000,000 in 1890; or some unexpected evil may befall us and retard our growth to $22\frac{6}{10}$ per cent., as in the decade of the rebellion, in which case our population at the next enumeration will be but 61,500,000. Time alone can tell.

THE SANITARY AND CONSTRUCTIVE SUPERVISION OF DWELLINGS.*

By LEWIS ANGELL, M. Inst. C. E.

That "An Englishman's house is his castle" is a fondly-cherished tradition. Be the Castle one of Indolence, Ignorance, Dirt, or Disease, who dare invade it? But a castle means isolation, a separation of neighbors by walls and entrenchments: and so long as the lord thereof and his retainers remain within the keep, their doings do not concern the outer world. But if the garrison sallies forth, committing devastation, are not the attacked justified in invading the castle? "Self-preservation is the first law of nature;" and if sanitary science, unknown to our mediæval ancestors, has taught the modern Englishman that the safety of his own well-ordered castle is dependent upon his neighbor's being also set in order, surely the most radical opponent of paternal government will concede that freedom must be qualified by the moral and physical rights of our neighbor. One of the earliest applications of this principle of compulsory sanitation was in the Vaccination Acts. Legislation also prohibits the exposure of infected persons and clothing. More recently the principle has been extended by local Acts requiring that the various kinds of infectious disease shall be reported to the medical officer of health. The extension of sanitary supervision to dwellings is therefore not only in harmony with established principles, and precedents, but is, in fact, a demand which has found expression in the recent establishment of societies in London and Edinburgh for sanitary inspection on co-operative principles. The latest development of the movement is the "London Sanitary Company," an association of eminent sanitarians who propose to combine philanthropic principles (limited) with the business of a big plumber. The company contemplates, as a "moderate estimate," an annual receipt of 10,000 guineas from 10,000 houses, independently of "entrance fees" and the profits from plumbing. The skilled advice of the highest medical and sanitary authorities will be secured, surveys and reports made by "an efficient inspecting satff acting under the direction of the company's engineers." The company will put dwelling houses in a perfectly sanitary condition, filter water, cleanse cisterns, prevent boiler explosions—in fact, sanitary repairs of all kinds will be "neatly executed at the shortest notice." A dividend of 20 per cent. is suggested by the prospectus, and $7\frac{1}{2}$ per cent. guaranteed by the plumber whose business has been acquired by the company as a "going concern," and whose services the com-

* Read before the Association of Municipal and Sanitary Engineers and Surveyors at Birmingham, on July 8.

pany have been fortunate enough to secure as "managing director." It is to be regretted that the aspirations of the company should stop short in so great a work. Surely ratepayers would not object if the company would also take over local boards as a "going concern," and guarantee a dividend, however small. A guinea rate per house per annum, officially levied by the sanitary authority, would very much more than maintain an efficient and responsible staff of sanitary inspectors, who would extend their protection to the poor as well as to the well-to-do subscribing shareholders, whom alone the "Sanitary Company" proposes to benefit. The fact of the existence of such societies, be they due to philanthropy or stock jobbing, raises a great question: Is such sanitary supervision necessary? and, if this be granted, by whom should it be conducted? That supervision is necessary will be admitted by all who, like the members of this association, have had any official experience. Thousands, probably hundreds of thousands, of houses are annually put together, we cannot say built, in such manner as to be dangerous to the lives of the occupants. Not only is stability disregarded, but every essential principle of sanitation ignored; the water pipes, the drain pipes, the very site frequently a huge dust bin, form a combination of contaminating influences which lower vitality and endanger life. This result is due as much to ignorance as to carelessness—a concourse of fortuitous evils rather than a conspiracy, although one regrets to have to add, as the result of official experience, that in too many instances it is also the result of the most wilful and wicked cupidity. As a practical illustration I may be allowed to quote my own official experience. For more than fourteen years past I have had the supervision of by far the largest district in the country governed by a local board; all other places of its size, and very many smaller, have municipal corporations. I refer to the district of West Ham, in Essex, which forms part of the the "outer ring" of "Greater London." It includes nearly 130,000 inhabitants, having more than doubled during the last ten years. Some 14,000 houses have been put up during my term of office, and at present they are increasing at the rate of about 2,300 per annum, equivalent to a new street of nearly 200 houses per month. These buildings require supervision. Being "over the border," we have no building fees as in the metropolis, a fact which induces the speculating builders to come over. If only a guinea were charged on each building—only *one* guinea, not the *annual* guinea invited by the "sanitary company"—my board would, independently of the rates, derive an income which would enable them to provide a qualified and responsible supervising staff not only to enforce the proper construction of new buildings, but to discover defects in old ones. The Local Government Board recently issued a series of model by-laws for buildings, involving very much detail; the advantage of their adoption was manifest, but adoption and observance are very different matters. I would have gladly urged their adoption by my Board had I not also felt there was no chance of their general observance over a district of $7\frac{1}{4}$ square miles with the staff I had at my disposal. The matter was so represented to the Local Government Board, and the imposition of building fees urged so as to provide a staff to carry out the by-laws; the reply was a courteous promise of consideration, but hoping, in the meantime, their "model" would be adopted. To this day the Local Government Board has done nothing to assist he officers, neither has my Board adopted the by-laws, for I hold it is bad policy to enact laws which cannot be enforced, which will be observed only by respectable and entirely disregarded by "jerry" builders. The infliction of penalties here and wholesale escape elsewhere is suggestive of official favoritism, and I maintain that we had better be without such minute laws than to bring them and the officers into disrepute and contempt by their habitual infraction. It is not, therefore, out of any want of appreciation or spirit of opposition that West Ham has not adopted the model laws of the Local Government Board. The moment the means are provided to maintain a staff for their observance, their adoption is certain. And, here in passing, I cannot refrain from giving public expression to a feeling present in the minds of every member of this asso-

ciation. As public officers, the Local Government Board impose their obligations upon us, they favor us with their criticisms, but in no single thing do they either consult, assist, or protect us. When an epidemic breaks out, locally or generally, one of the first suggestions made by sanitary authorities and local newspapers, in their panic, is to institute a house-to-house visitation; but, in fact, it is seldom attempted, and never effectually done, because it means expense, the ordinary staff being as utterly inadequate for such extraordinary efforts as it generally is unequal to ordinary requirements. But, whatever the extent of the staff, local authority has no power of inspection unless there be knowledge or reasonable suspicion of the existence of a special nuisance. In any case, the power of entry can only be enforced after compliance with certain formalities involving time and trouble; on the other hand, be the householder ever so anxious as to his safety, he cannot, of right, require an official inspection of his premises unless a nuisance is known or suspected to exist. However serious may be an epidemic, sanitary officers have no power to make house-to-house inspections. It does not appear to be unreasonable that local authorities should have the power, during epidemics as well as at all reasonable times, on reasonable grounds, to make house-to-house inspection, or that the ratepayers should, at all times, have the right to require such inspection. A short amending clause in the Public Health Act would readily effect all that can be reasonably expected. But to give effect to such power and satisfy the periodical demand, would impose on the local authorities the obligation of employing a sufficient staff of qualified engineering and sanitary officers. At present, at the best, sanitary inspection is not exercised in any sort of systematic manner—houses are built and drains are laid, especially, as has been said, in the suburbs of London, practically without effective supervision; and why? Not for want of power, but because of the paucity of the engineering and sanitary staff. The public are not sufficiently educated in the importance of sanitary principles to induce them to consent to the payment of the necessary staff out of the rates; but, as already shown, there is an equitable way by which ratepayers may be relieved of rates and reconciled to the existence of officials—viz., by putting the burden on the right shoulders and imposing fees upon the chief offenders against sanitary laws—those who build houses and derive profit therefrom. Such fees would, of course, go to the local authority, and not, as in London, to the district surveyor. Some years ago local by-laws required a certificate to be given before any new house was occupied, but the clause has been expunged by the Local Government as *ultra vires.* If fees are imposed by legislation, it should also be enacted that an official certificate should be granted on the satisfactory completion of a dwelling house. Such a certificate would be of real value, inasmuch as no one need then occupy a new house without its production. Sanitation would thus become a real increment of value in house property. Impressed with these views, I have, for years past, urged them, in season and out of season, long before the conception of the new limited sanitary *quasi* philanthropic companies. Some sixteen or seventeen years ago I joined in a memorial to the Home Secretary to enable local authorities to provide by fees for the proper supervision of buildings. A few years later I wrote to Mr. Gladstone on the subject, and he courteously promised to forward my letter to the proper department. For years past I have urged my own board and others to obtain Parliamentary powers to charge fees, and last year such a clause was included in a bill promoted by the West Ham local board. There was no opposition, local or otherwise; the Local Government Board not only did not object, but officially recorded its opinion that the circumstances of our case were so exceptional as to justify the application. The metropolis has long had such powers; Bristol has for forty years; even the little town of Eastbourne has such powers. With these precedents, and such exceptional reasons, a committee of the House of Commons expressed its willingness to hear our case, and waited for our evidence; but a power greater than Parliament, an *imperium in imperio*, put a veto on our clauses, and ruthlessly struck them out; this omnipotent power, Lord Redesdale, totally ignorant

of the place and the circumstances, is governed by the abstract idea that powers outside the Public Health Act should not be given to local authorities, totally disregarding the fact that every session exceptional powers are given to local authorities throughout the country in accordance with their varying necessities. No less than fourteen towns have recently obtained independent and varying local Acts for the report and registration of infectious diseases, such as smallpox, typhus, scarlet fever, &c. Why, in the name of all that is "abstract," should these fourteen towns be granted such exceptional powers not included in a general Act, applicable to all towns? Why should Eastbourne in 1879 obtain the powers which are refused to West Ham in 1881? Because, replies my Lord Redesdale, "exceptional circumstances" exist at Eastbourne. Eastbourne being a pleasant resting place from Saturday to Monday, I took the opportunity of investigating the "exceptional circumstance." A large part of the town is owned by the Duke of Devonshire, the very streets are called "Hartington," "Cavendish," and other of the family names. The duke's local agent is a leading member of the Local Board, and, whether or not he will acknowledge the soft impeachment, has the credit of obtaining the recognition of the "exceptional circumstances" applying to the pretty houses of ducal Eastbourne and those who dwell therein during "the season." That any circumstances exists, "exceptional" or otherwise, in Eastbourne which has not tenfold force in West Ham is distinctly challenged. In short, the few hundreds of the upper and middle classes who visit the toy-like town of Eastbourne are to be more exceptionally protected in their temporary dwellings than the thousands of toiling factory artisans who are compelled to live all the year round on the Essex marshes. My present object is not to discuss the wrongs of my own district, but to illustrate, by a typical case, the difficulty local authorities have to encounter in an honest and reasonable endeavor to cope with a great evil and promote sanitary well being. Here is a case in which an efficient supervision of the operations of building societies, speculating builders, and their accessory works requires an addition of some half-dozen inspectors to the local staff. "Pay them out of rates," say abstract legislators, "it is a municipal obligation;" but we municipal engineers and surveyors know too well the difficulty of obtaining decent payment for our own services to expect a sufficient assistant staff. Large towns like Liverpool, Manchester, Birmingham, or Leeds, may provide the necessary staff ungrudgingly, but it is not so everywhere. And why should such burdens be laid on the rates? Estate owners and builders are working for their own interests, many making large fortunes. Why, therefore, should they not contribute a fee, small in itself, but large in the aggregate, to provide the supervising staff, which their pursuit of fortune necessitates? Because, we are told, they already adding to the rateable value of the town; if so, they also receive, in common with others, the full value for their rates; but, as a matter of fact, such increase of buildings does not lessen the general rates, inasmuch as it involves a proportionate increase in the maintenance of roads, sewers, lighting, scavenging, police, &c., not to mention the school board and poor rates generally attending on the increase of a population. While abstract legislators, devoid of practical knowledge, are speculating, speculating builders are working; thousands of houses have been put up, and thousands more will follow before there will be any efficient control under a "general" Act. Imperial Parliament has no time for such trivial local matters. Surely there is as much necessity for "Home Rule" in England as in Ireland. Perhaps some of the members of this association will not assent to the full extent of my assertions. It is obviously derogatory alike to our pride and our efficiency as public officers to admit it; but I unhesitatingly assert, as the result of a long and varied private and official experience, that, however good our local by-laws, and however anxious and capable our local officers, as a matter of fact, there is no large town in Great Britain where, in its true meaning, sanitary supervision is efficient. Having quoted my official experience, I will crave a like indulgence in my private capacity in illustration of the defects of *old* houses. I have just entered a new residence; the

house is not new, but a good, substantial, well-built family dwelling of the last generation. In it there are as many as four cisterns; in that from which the drinking water is drawn sewer gas was "laid on" by no less than three "services" or direct connections with the house drains—viz., two flushing pipes to water closets and an untrapped overflow into the drain; each of the three pipes supplied sewer gas for absorption by the potable water; another cistern had two connections with the drain—a closet flush and an overflow pipe; a third cistern was also connected with the house drain by an untrapped overflow pipe; but, curiously enough, the fourth cistern, not intended for the supply of drinking water, was the only one unconnected with the drains. There were also two sinks in communication with the drains. In fact, within the house there were no less than nine drain connections with sinks and cisterns, exclusive of water closets. All this was altered at considerable trouble and cost, much greater than if correctly done at first. No sewer gas can now enter the house or contaminate the water. The new arrangements were regarded as "fussy," and sarcastically described as "very scientific," and as a further comment upon the sanitary theories thus practically asserted was quoted the fact, which is undoubtedly true, that in the same house the preceding family had for very many years lived very healthy lives. The obvious reply is that, according to all the laws of sanitary science, the inmates of such a house *ought* to be ill; under such conditions escape must be due either to the "survival of the fittest," that is, the inherent resistance of robust constitutions, or to the protection of a special Providence which cannot be tempted with impunity, for those who know the law and disregard it may expect and deserve "to be beaten with many stripes." Let me quote another case or two. In the civic palace of the Lord Mayor of London, $\frac{3}{4}$in. of floating fungi scrub was recently found on the surface, and $\frac{3}{8}$in. of mud at the bottom of the cisterns, while a bottle of water on his lordship's table contained hundreds of nematoid worms. Nor is the West end of London better than the City, for in the cistern of the Athenæum Club, St. James's, was found a large quantity of offensive mud and animal organisms. The discoveries as to the insanitary condition of the Government offices are only too notorious. In poor neighborhoods and small houses, the water butts and cisterns, especially in London, are situated in close courts and contiguous to every kind of filth; generally placed over the water closet, near a sink and dust bin, untrapped pipes communicate directly from the cistern to the soil drains. They are frequently uncovered, consequently the water absorbs the impurities of the surrounding atmosphere; they are not cleaned out from one year's end to another, so that they accumulate mud and slimy vegetation. But it is unnecessary to multiply instances, or enlarge on the existence of evils so well known to us sanitary officers. To a condition of things such as above described, in houses new and old, is undoubtedly due the lassitude, the illness and the death of thousands whose inherent power of resistance is unequal to the fight. Those who are subject to such influences stand very much in the relation of the unvaccinated to small-pox; they *may* escape, but the chances are obviously against those who neglect the protection so well known and so easily attainable. I think it has been sufficiently proved that sanitary supervision is needed in our dwellings, and that it is equally obvious the work should be a public and an official one, and not undertaken by amateur or stockjobbing companies whose philanthropy is confined to shareholders. That the work has not been done before is not the fault of us officers; that it can be done, if paid for, is the very argument on which the companies are founded; but that shareholders should be protected and the poor neglected is a proposition too monstrous to be discussed. Sanitary protection is the legal right of all without subscription or "entrance fee" beyond the obligatory general charge of rates. We have seen how means can be provided without increasing the rates by charging the costs on those who can and should provide them. Surely fees are sufficiently recognized in England; from a railway station to a Government office, can any information be obtained or act done without a fee? Why a fee should be imposed on every new house in London,

Bristol, and even little Eastbourne with admitted advantage, but no other town should share in such an advantage, is inexplicable, unless it be to leave an opening for a new development of commercial enterprise in the formation of Sanitary Protective Associations (limited). It is true that an Englishman does not like officialism. We know, by experience, that it is in his nature to put himself in a fighting attitude towards officials ; but if we must needs have officers, it is better to have the responsible officer of a legally constituted and recognized authority, than irresponsible employes of a limited liability company. It is a disgrace to our legislation that in England, the cradle of sanitary science, there is room for such companies. We read in the *Sanitary Engineer* of New York: "Chicago has found the results of her system of factory inspection so beneficial that she is now applying it to tenement houses. Six inspectors are now making a critical inspection of the tenements, and will continue it until the 7,000 tenements which, according to the *Chicago Times*, there are in that city, shall have been examined. The *Times* says that the work has now been reduced to a system, and complete records are kept of all work done. These records consist of date, location, ward, district, name of owner or agent, description of building, number of rooms, number of families, with the number of persons in each, sanitary condition of the building, action taken in abating nuisances found, and explanatory remarks. Each inspector is provided with blanks, which he fills out at the close of each day's work. His report describes the condition of the plumbing, drainage, the local sanitary condition, and notes any violations of the city ordinances. In case anything is found about premises which is detrimental to health, a notice is served on the owner or agent, who is required to comply with the ordinances of the city relating to the abatement of nuisances." We also read that in New York and other States household plumbing is placed under official inspection. This is the outcome of more advanced public opinion in America. I have already hinted that the British ratepayer is not yet sufficiently educated in sanitary principles ; he does not yet appreciate the maxim that "Prevention is better than cure," that it is very much cheaper to employ a few inspectors than to pay the rates consequent upon preventible disease and the untimely death of the humble bread winner. I therefore submit the following propositions : That a more efficient and extended supervision of the sanitary and constructive details of all dwellings is necessary. That such supervision should be conducted by the responsible officers of the local sanitary authority. That it is just and expedient that fees be imposed on all new buildings, to provide the cost of such supervision. In conclusion, we must hope more from education that officialism. If sanitary science were studied in our schools, and our youth taught to avoid vitiated air as they would false quantities; if elementary hygiene were recognized as equal in importance with simple equations, many a good and useful life would have been saved for the commonwealth. But now, in the selection of a house, more attention is given to a "dado," a "cornice," and "æsthetic" ideas, than to the cistern, sink, or other vital conditions of health. How difficult even is it to obtain compliance with the most simple and obvious sanitary rules in one's own house! For example, whatever may be the radical defects of construction, sewer gas may at least be neutralized and kept out of the house by always keeping the closet door shut and the window open ; but we almost invariably find the reverse rule to obtain, the window is *shut* and the door *open*, especially at night, when the house is almost hermetically sealed, and a current of sewer gas, induced by the warm air, enters our sleeping room at a time when our power of resistance are at their lowest. In large hotels we find at the end of a long corridor of bedrooms a battery of closets with every window shut and every door open, unless some "fussy" people, like ourselves, take the trouble to reverse the arrangement by opening the windows and closing the doors. It is unnecessary to say more. The canon laws of house sanitation are very simple and easy to observe. Builders will say that "doctors differ;" it is not so : there is no differing upon general principles ; they are so well known to every member of this Association, that it is unnecessary to state them ; but for the advant-

age of the general public I may be excused for repeating some of the more important of them. There should be no connection between the house and the sewers excepting for sewage; the soil pipe should not by any chance ventilate itself into the house; all other drains or pipes from cisterns, baths, lavatories, sinks, &c., should discharge into the open air; the drinking water should have no connection with the closet. These are cardinal rules, the neglect of which may be fatal; but nearly everyone can discover for himself such neglects. There are, of course, other matters more difficult to detect. We have only stated principles and facts, well known to all sanitarians, which have been repeated over and over again. But sanitarians are few, and the population is large; the population is also careless, and it is not until an unexpected, cruel and irreparable death has smitten a family with deep affliction, that conviction is forced upon the survivors, and alas! when too late, they recognize preventible causes and adopt the simple precautions and protections which, at present, are almost exclusively the privileges of the occupants of workhouses and jails.

ON METERS FOR REGISTERING SMALL FLOWS OF WATER.*

By J. J. TYLOR, of London.

From "Iron."

THE writer proposes to commence, by a short account of the chief water-meters which have been used in this country, mainly indeed for purposes of trade supply, but also occasionally for domestic supply; and also of those which are used on the Continent for domestic as well as trade supply, and which can be made available for England. In each case his special object will be to show how far the design is effective in the measurement of *small* flows.

Parkinson's Meter.—This is, in fact, an adaptation of the gas-meter, invented by Mr. Parkinson, to the measurement of water. It was described in a paper read before the Institution in 1851 (Proceedings, January, 1851, p. 19). A trough, in which the height of the water-level is maintained constant, by means of a ball-valve, passes the water entering it from the main through an overflow pipe into a rotating drum, divided into compartments. The water enters a compartment, situated on one side of the vertical axis of the drum; and thus the weight on one side being increased, the drum revolves, the full compartment sinks, and the water escapes into the case supporting the meter, and thence to the exit pipe. As the first compartment recedes another compartment takes its place, and is filled and emptied in its turn. The revolutions of the measuring drum are recorded by a train of wheels indicating on a dial; and the contents of the compartment being known, the measure is at once given. The character of this meter, which is largely in use, necessitates its being placed on the highest point of the house service. This is an objection, both on account of the exposure to frost and of the inconvenience to the consumer, in the meter inspector having to pass through the house up to the highest rooms, in order to examine the meter. The meters are, however, very reliable, and are capable of registering a very small flow of water with exactness.

Kennedy's Meter.—This meter (already described in the Proceedings, 1856, p. 156), consists of a cylinder, in which a piston, packed with a rolling ring of india rubber, works upwards and downwards. Each stroke of the piston is recorded on an index by means of a rack on the piston-rod, driving a pinion, which is fixed to a tumbler. This tumbler, by falling over its center of motion, reverses a four-way cock, serving as a supply and discharge valve. These meters are extremely reliable for any quantities passed by the meter, as long as the packing of the cylinder remains quite sound, and as

* Paper read before the Institution of Mechanical Engineers.

long as the ground-in four-way cock does not leak or jam fast. Irregularity in the section of the india rubber ring sometimes causes the piston to jam or become tilted, so that the water may pass without registration. In one of the author's experiments, a meter of this type, fresh from the maker's hands, permitted water at the rate of the full bore of a ½-inch pipe to pass without registration, owing to the fact that the piston was somehow forced by the water past the limit of its stroke, and thus got out of gear. These meters are somewhat noisy in action; and the reversal of the current at each stroke causes, at the higher pressures, considerable shocks in the mains. During the reversal of the valve, water passes without registration, though for a very short space of time; and, if the reversing balance is stiff, the meter may possibly stop at this point.

Frost's Meter.—This consists of a piston, fitted with leather buckets, working in a cylinder. The reciprocating motion of the piston is caused by a double set of valves, with ports similar to those of the steam engine. A three-port valve, worked by a cam on the piston-rod, gives motion to an auxiliary piston, set at right angles to the main cylinder, and working the main induction and exhaust valve, which is also a three-ported valve. The meter cylinder is lined with brass, and the piston has double leather buckets. Leather buckets are liable to stick and get corroded if left standing, and also wear faster than the rolling ring of the Kennedy meter. The flat three-port valves are also liable to wear round, and the mechanism is more complicated than Kennedy's. The meters, however, weigh much less and are quieter in action, registering with great accuracy at high and low velocities, as long as they are in good order. Frost is a dangerous enemy to all classes of piston meters, because, owing to their size, they cannot be cheaply protected from changes of temperature; and the expense of repair is great in such case, because the cylinder is usually the part which gives way. The water-power consumed in working these meters is considerable at quick speeds, as a heavy, tight-fitting piston has to be moved; and, in case no water passes through the meter for several weeks, the piston is apt to stick. These meters are also noisy in action, and the flow somewhat intermittent. For these reasons they are not so well adapted for small flows or for domestic purposes, as inferential meters.

Siemens' Turbine Meter.—This was brought out in two forms, one (described before the Institution, Proceedings 1853, p. 12, and 1856, p. 113), consisting of a vertical Barker's mill or reaction turbine; and the other of a turbine driven by water entering at the circumference of the wheel, and finding its way out at the center. The latter form was first tried in practice; and the writer has lately seen some of these meters, which, though useless for measuring small flows of water, seemed to be reliable for large flows. Messrs. Guest and Chrimes, the makers of these water meters, appear to have definitely adapted the Reaction Turbine; in which form this water meter has come into very extended use, both in England and abroad. The modified construction of this meter includes a reaction turbine rotating on a steel-shod pivot, provided with means of lubrication. The water enters at the upper part of the wheel or drum, which, at the point of entrance, has its neck suddenly contracted, so as to form a more or less water-tight joint, with the stationary neck conducting the water to the wheel. The water, passing downward to the larger and lower portion of this pear-shaped drum, makes its exit into the case or meter box through contracted tangential openings. The friction of the water in these openings, as well as the resistance of the more quiescent fluid in the case, causes the drum to revolve. Vanes, or drag-boards, as Dr. Siemens calls them, projecting from the moving part, prevent the increase in the velocity of the wheel being more than is proportionate to the increase in the velocity of the water; thus practically ensuring that the number of revolutions per unit of water will remain constant, at whatever speed the water may pass. It is evident that the neck forming a joint between the moving drum and the stationary case is the weak point of this meter, since any leakage at this point allows water to escape without measurement. The bearings of this neck cannot be made long or very close-fitting, as the friction of the drum is a very important element, when small flows have to be measured. Again, the neck, being

of considerable diameter, is liable to corrode and set fast, in case the meter remains long at a standstill. One great advantage of this water-meter is that the correct action of the drum does not depend on its exact fit into the outer case; so that considerable wear of the toe-piece, or vibration through the wear of the bearing, does not much affect the registration, or stop the drum by causing contact with the case.

Siemens' Fan Meter.—This differs from the former in the substitution of a wheel with blades for re-action turbine. This wheel or fan is driven by the impact of the water through oblique circular apertures in the casing, and the water, after setting the fan in motion, passes upwards towards the exit. Its velocity of rotation is checked by projecting plates, equivalent to the vanes or drag-boards of the former meter, but placed on the upper part of the case. The regulation of the meter is effected by alterations in the size of these projecting plates. This meter, which is largely used on the Continent though but little known in England, has proved successful when carefully made. The higher position of the outlet, however, diminishes the efficiency with small flows, as the water, if not projected with considerable velocity, tends to take the direct path from inlet to outlet without impinging on the blades of the fan. The wearing away of the toe-piece also causes the fan at length to come in contact with the case; and the fit of the fan in the case determines the accuracy of the registration. Further, the position of the case, below the level of the outlet, makes the meter liable to be choked by sediment; and, the case being of iron, a great quantity of rust finds its way into the moving parts, and is apt to set the fan fast in case of temporary disuse. For small flows this meter has the advantage over the other design, because in the absence of the turbine neck all water has to pass the blades of the fan, and so produces an effect on the registration as long as the quantity passing is sufficient to move the fan at all.

Tylor's Meter.—This meter, like the last, consits of a fan revolving in a case, but both fan and case differ in important points from those of Dr. Siemens. Water entering by oblique rectangular vertical openings, sets the fan in motion, and escapes at other openings on the same level, in such a way that two or more blades of the fan are always in the direct path of the water in its natural process through the meter. The fan itself consists of a solid wheel made from a preparation of india-rubber, very strong, and of almost the same specific gravity as water. It is provided with blades or teeth, which in some cases, especially for the larger sizes of meter, are made of brass. In that case the shoulder, where the blade joins the boss, is placed at an angle to the axis of the spindle, so as to tend to lift the fan at the higher velocities, and thus avoid wear of the toe-piece. The same result is obtained in the india-rubber fan by its low specific gravity. The toe-pieces for all sizes of meter are made of a special preparation of bronze, to avoid the destruction by rust to which the toe-pieces of other rotary meters, having steel points, are liable. The case is of brass, and is formed of two half ellipses, so placed together that at their junction a projection is left at each side. The fan only approaches the case at four points, namely, where the water comes in and goes out, and at the projections. The object of this peculiar form is to prevent the choking of the meter by sediment or rust, and also to prevent the current of water from continuing to turn the fan after the source of supply is shut off. This obviates the common difficulty in rotary meters, namely, that the moving part of the meter continues to rotate for some revolutions after the water has ceased to pass. This motion is partly caused by the *vis viva* of the fan, and partly by a current of water continuing to revolve in the lower part of the meter case, and carrying the fan round with it, after flow through the meter has ceased. In the present meter the projections in the case regulate the movement of the fan at the greater velocities, so that a unit of water moving at a high velocity is prevented from causing more revolutions of the fan than a unit of water at lower velocity; while the centrifugal force of the water produces a back current from the projections, and breaks up any tendency the water may have to continue rotating after the flow through the water ceases. Another improvement in this meter is an application

for regulating the speed of the fan by a counter current of water, so arranged that it is adjustable from the outside of the case. This is of great convenience in testing, and also for persons making use of these meters, since any error in registration, springing from long use or accident, can be remedied without taking the meter to pieces or sending it back to the manufacturer. The defect of this meter is that, like all rotary meters, it is liable to pass a certain quantity of water without registration. This quantity can be limited to an amount comparable with the minimum registration of piston meters; but at the expense of rendering the meter too delicate for use in corrosive water. In concluding this part of the paper, the author wishes to draw attention to the great influence of Dr. Siemens' invention on the introduction of rotary meters, and to the fact that to his original designs all the rotary meters which have come into use owe their principles of construction.

Measurement of Small Flows.—In practice abroad, where rotary meters are mostly employed for domestic supply, a meter having moderate accuracy with very small flows is found the most advantageous. Cisterns are not in use, and the consumer cannot therefore conveniently defraud the company by allowing the water to trickle slowly. As a matter of fact, it is certain that in ordinary use but a small quantity of water is drawn at very slow speeds in domestic supplies. Accordingly in Russia, Germany Austria, Italy, and France, the rotary meters described in this paper are used almost exclusively for domestic supply, and the payments for water are collected according to the registration of the meters. In England detailed experiments have always been made in practice, as far as the author is aware, with quantities sufficient for trade supplies, and therefore run at considerable speeds. If, however, meters are to be employed for domestic service, it will be necessary to register small quantities, at least in cases where cisterns are used, and the question arises how far the existing meters are capable of performing this function. Now the experience of the Continent proves that there is no difficulty in registering small quantities, whether with a rotary or piston meter, provided they are not drawn at a very low speed. If the speed be very slow, then a rotary meter, at any rate, becomes less reliable. Assuming that this is not the case with the piston meter, we may fix a rotary and piston meter together on the main of the dwelling house, and then see whether there is any marked difference between the registration of the two, indicating that a portion of the water has been drawn very slowly. Three experiments of the kind are given in Tables I.-III. annexed, for houses of different classes: and it will be seen that while the difference is usually small, the rotary meter shows the greater flow, proving that in practice no error arises from this cause. In these cases both meters were tested with measured quantities, both before and after the experiments, in order to make sure that they were in good order. Table IV. gives a similar trial carried out in Edinburgh, and here the rotary meter shows a distinct deficiency; but the variations between the two piston meters are also noticeable.

House Meters.—The general question of the introduction of meters for domestic supply in England is a very large one. Into its financial and economical aspects the writer does not propose to enter; but only to point out the great advantage of meters as a means of preventing waste, and thereby of increasing the efficiency, and diminishing the cost of the service, under whatever system that service may be administered. If the water companies were willing to grant supply by meter instead of by rate, there would be no difficulty in arranging existing meters to fulfil any conditions necessary. To provide against loss of water by waste from the main, or in supplies not controlled by a water meter, some account of the system introduced by Mr. Deacon at Liverpool, with his waste-water meter, and carried out by Mr. Muir of the New River Water Company, and other engineers, will prove of service. The following is a description of an apparatus for the same purpose, which has been applied by the author to the existing Taylor meter. Above the meter, the movements of which are to be recorded, and fixed to the upper flange, is placed clockwork, so constructed as to move a strip of paper, about 1 inch broad, horizontally, and with an intermittent move-

ment, under a pencil or pen free to move transversely. This pencil or pen is connected by a cam and train of wheels with the registering pinion of the water meter, in such a way that the movement of the pencil across the strip of paper corresponds to 500 or 1000 gallons registered by the water meter. The completion of the movement of the pencil across the paper is marked by its sudden return to the side of the strip of paper whence it started, and the interval between the ascending serrated mark and the return vertical mark corresponds to the time occupied in the passage of the above quantity of water. The time is also marked every hour independently by a pricker connected with the clock, as a check.

In some of the recently erected workmen's dwellings it has been ascertained that the total consumption of water, including washing of clothes, does not exceed six gallons per head, and this is for the better class of artisans. The author has made many experiments on this point, and whilst the differences in consumption, in houses of the same class, are found to be very large, it is clear that six gallons per head is really sufficient. Tables V. and VI. give two cases of this kind, in houses of very similar character. The large fluctuations from day to day will be remarked, and also the fact that in one case the consumption per head per diem was $14\frac{1}{3}$ gallons, and in the other $4\frac{3}{4}$ gallons only. In the latter case, however there was also a small rainwater cistern in use. Again, in houses of the middle classes, it is known that the quantity of water actually used for cooking, washing, and all other purposes except baths, is not more than ten gallons per head, and for baths five gallons per head will be a very ample allowance. It will therefore be on the safe side to assume that the actual consumption per head for all purposes should not exceed fifteen gallons for medium-sized houses, and ten gallons for small: making in the latter case a large allowance for the increased consumption in single tenements, as compared with dwellings in flats. But it is known that the London waterworks supply on an average upwards of 27 gallons per head of the population; so that it appears that nearly half the total supply is absolutely wasted.

If by a proper system of domestic meters this enormous waste could be checked and brought within proper limits, the advantages, both to the water companies and to the consumer, must obviously be great. The increased pressure and service, resulting from the diminished drain on the mains, would enable a constant supply to be maintained at the top of every house during the day; and would thus do away with the need of cisterns for storage, which are always stagnant and often polluted. To the companies the reduction in the cost of pumping and other expenses would pay for the whole expenses of supplying and maintaining the meters, and leave a very large surplus. For instance, the report of the Committee in 1880 shows that the average gross income of all the London Waterworks is at the rate of less than 7d. per thousand gallons, and that the trade supply is about one fifth of the whole. Now if the water rates were raised by a charge of 1s. per thousand gallons of measured water, divided into average charges of 6d. for trade and 1s 2d. for domestic purposes, it will be seen that the water companies of London would (if waste in the mains be limited to 8 per cent.) profit to the extent of 4d per thousand gallons on the present supply. On the other hand (as shown by Table V.) even the most extravagant consumer would for an efficient supply pay less than he now does: but as long as his fittings were out of order he, and not the water company, would pay for the wasted water.

TABLE. I.

Experiments carried out at the Lincoln Waterworks, with Constant Service, showing the Relative Monthly Registration of a Rotary and Piston Water Meter.

Month.	Rotary Meter, gallons per diem.	Piston Meter, gallons per diem.
March	97	96
April	102	101
May	199	177
August.....	83	77
October.....	90	86
Total for 5 months....	19,575 Gallon.	18,188 Gallon. (7 per cent. less).

The consumption in this experiment corresponds with that of an ordinary workman's house in London, with con-

stant supply, containing 8 persons, and using on an average 13.07 gallons per head per diem.

TABLE II.

Experiments with Piston and Rotary Meters both ½ inch, on a house and tobacco shop, containing 8 persons of whom 2 were away from 6 A. M. to 6 P. M. 1 bath, 2 w. c. s.

Date.	Rotary Meter. Average gallons per diem.	Piston Meter. Average gallons per diem.
1880.		
Dec. 23-26. ..	117	115
Dec. 27-30. .	182	105
1881.		
Dec. 31 – Jan. 3	152	138
Jan. 4-Jan. 7.	132	118
Jan. 8-Jan. 11 (Frost).	145	122
Jan. 12-Jan. 14 (Severe frost)	166	150
Average....	147	140 (4.75 per cent. less)

N. B.—On January 14th, the pipes were frozen till Feb. 8th, when the piston meter burst. The rotary meter recorded 240 gallons on Feb. 9th, and 100 on Feb. 10th.

This case represents a large class of houses used as small shops, with two or three lodgers besides the family. The average consumption is 17.75 gallons per head per diem.

TABLE III.

Experiments with Rotary and Piston Meters on main of a house in the Chelsea District. Number of family 12 to 14 persons. 2 baths, 4 w. c. s. Supply constant during daytime.

Date.	Rotary Meter Gallons per diem.	Piston Meter. Gallons per diem.	Remarks.
Feb. 17	150	Out of order	14 persons in a house.
" 18	215	"	"
" 19	245	"	"
" 21	240	"	Family left
" 22	300	290	Cleaning
" 24	515	530	Cleaning family returned
" 25	535	500	Family left
" 26	420	410	Leaky ball valve repr'd.
" 27	425	405	
" 28	425	415	Family returned.
Mar. 1	474	470	10 persons in house.
" 2	500	490	"
" 3	465	480	"
" 4	313	490	"

This was a house occupied by a member of Parliament, at a rent of £ 350 per annum. The average consumption, from Feb. 23d to April 11th, had been at the rate of 22.5 gallons per head per diem. But previous to repair of fittings on Feb. 26th, the average consumption was at the rate of 31.3 gallons per head.

TABLE IV.

Experiments with Piston and Rotary Meters carried out by Mr. Coyne, Engineer of the Edinburgh Waterworks, for his own information. Meters were placed on a public service and about 70 feet; constant service.

No. of Experiment.	Duration of trial.	No. of Days.	Rotary Meter. Gallons registered.	Piston Meters. No. 1 Gallons registered.	No. 2 Gallons registered.
1	April 21, 1879 to Feb. 14, '80	297	130,012	out of ord.	152,800
2	Feb. 15, 1880 to June 2, '80	109	48,090	out of ord.	54,000
3	June 2, 1880 to Aug. 16, '80	74	47,700	34,000	37,350
4	Oct. 27, 1880 to Feb. 10, '81	116	54,100	38,100	38,700
Tot.	April 21, 1879 to Feb. 10, '81	596	278,110	—	306,050

TABLE V.

Quantity of Water registered by ½-in Rotary Meter in a House containing 5 people, all washing done at home, 1 bath, 1 w. c. Intermittent supply.

Date.	Per Meter Gallons consumed.	Gallons per Head daily.
Sat. Nov. 20	210	42
Sun. " 21	60	12
Mon. " 22	90	18
Tues. " 23	50	10
Wed. " 24	40	8
Thurs. " 25	50	10
Fri. " 26	65	13
Sat. " 27	80	16
Sun. " 28	60	12
Mon. " 29	80	16
Tues. " 30	60	12
Wed. Dec. 1	50	10
Thur. " 2	40	8
Fri. " 3	100	20
Sat. " 4	90	18
Sun. " 5	50	10
Mon. " 6	80	16
Tues. " 7	60	12
Wed. " 8	100	20
Thur. " 9	30	6
Fri. " 10	60	12

N.B.—3010 gallons consumed in six weeks, ending Dec. 10. Daily average $70\frac{1}{3}$ gallons, or $14\frac{1}{3}$ gallons per head. Rent of house £40 per annum; water rate, 41s. Water used by meter in six months was 13,080 gallons, which at 1s. 2d. per thousand is equal to 30s. per annum.

TABLE VI.

Quantity of Water registered by a $\frac{1}{2}$-in. Rotary meter, fixed on a House in the Lambeth District, containing 7 rooms: 1 w.c., garden 120 by 16. All washing done at home. Number of family, 6.
Contents of Cistern 7.7 cubic feet, or about 50 gallons. Meter gave 50 gallons when tested at commencement of trial.

Date.	Gallons per Day.	Gallons per Head per Day.
Nov. 20.......	30	5.0
,, 21.......	30	5.0
,, 22.......	20	3.3
,, 23.......	30	5.0
,, 24.......	20	3.3
,, 25.......	30	5.0
,, 26.......	55	9.1
,, 27.......	5	0.8
,, 28.......	40	6 6
,, 29.......	10	1.66
,, 30.......	20	3.3
Dec. 1.......	20	3.3
2.......	25	4.1
3.......	30	4.1
,, 4.......	5	0.8
,, 5.......	20	3.3
,, 6......	50	8.3
,, 7.......	45	7.5
,, 8.......	45	7.5
,, 9.......	50	8,3
,, 10.......	40	6.6

Total water in 124 days, 3180 gallons; average per diem, 25.56 gallons; average per head per diem, 4.75 gallons. Meter, when tested at different intervals during trial, showed 48 gallons for contents of cistern. The supply being intermittent and the meter placed near the cistern, this error is probably due to air in the pipes, as the meter was exactly correct when tested at the manufacturers. The cistern was allowed to fill with the ball valve closing gradually, in the usual way, in these intermediate tests. In reference to the small consumption in the house, it appears that a rain-water cistern containing 50 gallons is in use, the water from which is used, when obtainable, for any purposes except for drinking and for c ›oking.

A NEW invention for coating iron and steel with iridescent copper, says the *Revue Polytech*, is the work of Dr. Weil, of Paris. First, thirty-five parts of crystalized sulphate, or an equivalent amount of any other salt of copper, are precipitated as hydrated oxide by means of caustic soda or some other suitable alkaline base; this oxide of copper is to be added to a solution of 150 parts of Rochelle salts, and dissolved in 1000 parts of water; to this 60 parts of best caustic soda, containing about 70 per cent. N*a*O, is to be added, when a clear solution of copper will be formed. The object to be coppered is to be cleaned with a scratch brush in an alkalino-organic bath, attached as a cathode, immersed in the coppering bath, and treated with the usual precautions, when it will become rapidly coated with an adherent film of metallic copper. As the bath gradually loses its copper, oxide of copper, as above prepared, should be added, to maintain it in a condition of activity, but the quantity of copper introduced should not ordinarily exceed that above prescribed, as compared with the quantity of tartaric acid the bath may contain. If the quantity of copper notably exceeds this proportion, certain metallic iridations are produced on the surface of the object. These effects may be employed for ornamental and artistic purposes. According to the time of the immersion, the strength of the current, and the proportion of the copper to tartaric acid, the iridescences may be produced of different shades and tints, which may be varied or intermingled by shielding certain parts of the object by an impermeable coating of paraffine or varnish, while the iridescent effect is being produced on the parts left exposed. All colors, from that of brass to bronze, scarlet, blue and green may thus be produced at will.

THE Italian Minister of Public Works has given orders for surveying a direct railway line from Naples to Rome, *via* Gaeta and Terracina, which was proposed in 1871 by the engineer Danise. Rome could be reached by that route in three and a-half hours, while now double this time is employed. Strategical considerations will have some weight, as the new line would give mutual support to the fortress of Gaeta and Capau.

SUSPENSION BRIDGES OF ANY DESIRED DEGREE OF STIFFNESS;

OR, THEORY OF EQUILIBRIUM OF A LOADED ELASTIC BEAM SUSPENDED FROM AN ELASTIC PARABOLIC CATENARY.

By C. B. BENDER, C.E.

ONLY few combinations of two elastic systems admit of a strict analytical treatment, and many combinations are only the result of arbitrary guessing without a sufficiently clear understanding of the acting forces.

Such designs, when executed, represent only so many unscientific experiments on a large scale.

The combination, however, of a homogeneous elastic beam suspended from a flexible catenary, is one of the few which are capable of a tolerably rigid analytical treatment.

It is a very useful combination.

Though frequently examined—so far as known to the writer—it was always supposed to be made with a beam so stiff that the assisting influence of the *distortion* of the parabolic catenary could be neglected.

That this supposition may lead to considerable errors, will result from the solution of the problem now presented, and worked out by the writer at the commencement of the year.

The combination of catenary and suspended beam is especally useful for very great spans, and has become more so since, thanks to the inventions of Messrs. Siemens and of Sir H. Bessemer, steel wire of great strength and uniformity can be produced in great masses at a reasonable cost.

It is now possible to construct galvanized steel wire cables of 70 and more tons of ultimate strength per square inch of metal of the finished cables. Moreover, wire is furnished (first in Germany, where the wire industry occupies many works, and not only supplies nearly exclusively the home market, but also brings 70,000 and more tons of this article yearly to export) in coils of about a hundred weight each, so that the joints of cable wires are more than 1500 feet apart.

Since the capacity of elastic material for absorbing tensional impacts within the elastic limit, increases in direct ratio of the lengths, long wires are capable of withstanding the influence of movable loads better than riveted structures, or even of ordinary bridge links, which were never made in lengths greater than a little over 50 feet.

By good connections, about 5 to 10 per cent. of the original strength of the wire is lost. Eye bars of 25 feet length, if made 6″ wide, require 16 per cent. additional material for eyes and pins. If made 3″ wide only 8 per cent. would be needed. Galvanized steel wire of No. 8 gauge can be furnished in great masses with an ultimate strength of about 160,000 pounds per square inch area. For steel eye-bars not more than 70,000 pounds must be counted on, and for good ductile iron eye-bars 50,000 pounds. Wire is considerably dearer per ton than bars, but requires only machine labor to make the connections. It is easily put in place, but requires much time for its manufacture into cables.

For very great spans cables seem to have the preference, not only on account of their durability, due to galvanizing and wrapping, but, also, because their strains are known with great certainty, and because of the great distance of wire joints which permit the adoption of a lower factor of safety. (Compare "Cable Making for Suspension Bridges," by Wilhelm Hildenbrand, the scientific and conscientious assistant, since the commencement of the East River Suspension Bridge, of the late John A. Roebling and his son, W. Roebling, the engineers of that structure). The suspended beam not only has the office of distributing the concentrated loads, and of neutralizing the greater part of the momenta caused by one-sided loads, but also furnishes a sufficient quantity on both sides of the bridge floor, which serves to form chords for the horizontal wind bracing.

Additional arrangements, as inclined stays, are not only not needed, but lead

to waste of material and labor, because the point of attachment of each stay, under certain positions of the movable load, is taxed with a high moment of flexure. These stays, and similar additional appliances, lead to uncertainty of all strains, and hence to unscientific rule-of-thumb design and to disturbance, under the influence of changing temperatures of the conditions of equilibrium.

The *beam, if properly designed*, is all what is wanted; it is *necessary and is sufficient!* It does away with those uncertainties, and gives the greatest simplicity and economy for the greatest possible spans.

In order to examine the conditions of equilibrium of this useful combination reference is had to the following diagram and notations.

Let these represent:

ACB, the original parabolic catenary.

A′C′B′, its position in equilibrium under the loads supposed.

$2b$, the distance AB=A′B′, its span.

H, its original depth.

$y=\varphi(x)=h-\frac{2H.x}{b}+\frac{H..x^2}{b^2}$ its original equation.

O′, the origin of co-ordinates.

O′O″, the positive side of the abscissæ x.

O′A, the positive side of the ordinates y.

πx, the intensity for the abscissæ x of forces acting in suspenders, supposed to be infinitely close together, and representing a load per unit of length of x.

Q, the constant horizontal component of the tension of the cable A′C″B′ for any abscissæ x, it being the result of all weights acting upon the system. A flexible cable is supposed.

E, the modulus of elasticity of material, it being supposed to be constant throughout.

h, the original length of the longest suspender.

$h-$H, the original length of the shortest suspender.

O′O″$=2b$, the length of the suspended beam.

R_1 a possible *positive* reaction, the positive sign being used for supporting forces acting upwards towards the positive y.

W_1 W_{11} W_{111}, negative concentrated forces: weights.

$2b$. K, an uniform permanent weight, K being its intensity″ per unit of length of beam.

$z\,p$, another uniform and movable weight, $z=$O′z being variable.

l_1 l_{11} l_{111}, the levers taken for O′ of the weights W_1 W_{11} W_{111} in their position on the system in equilibrium.

M′o, the moment of all weights W, p and K for O′.

M″o, the moment of all weights W, p and K for O″.

These moments are connected by the equation $M'o+Mo''=2b\,(W_1+W_{11}+W_{111}+\ldots+2\,b\,K+z.p)=$ span × sum of all weights.

I, the constant moment of inertia of the suspended beam. This is supposed to be homogeneous, and of such nature that its deflections are not influenced by the shearing forces (web members), but only by the moments of flexure (chords or flanges). A moment of flexure for a certain abscissa is positive, if the radius of curvature at the point contemplated is directed towards the positive side of the y, or if the center of curvature is above O′O″. The second differential quotient, therefore, of the equation of the curve of flexure for that point is positive, and the positive moment means a curve concave towards the side of the positive y, with pressure in top fibers and tension in the bottom fibers of the beam. A negative moment arises from a negative second differential quotient, causes a curve of flexure, which is concave towards the negative y, and causes tension in the top and pressure in the bottom fibers of the beam.

A shearing force is considered positive if acting in a sense opposite to that of the weights imposed upon the bridge. For a certain abscissa x, it is equal to : R_1 plus all forces $\pi x.dx$ less the weights between the point O′ and the point contemplated.

In accordance with these notations, suppositions and explanations, the problem consists of finding the equation of the elastic curve of the beam. Its unknown equation $y=f\,(x)$ is to be found where y are ordinates, as distinguished from those of the cable, which are denoted with y. If, for instance, the beam deflects, which here means that y is negative, and if the suspender, for a certain $x=x_1$, originally had the length y and

now becomes $y(1+\varepsilon)-\varepsilon$ being the specific extension of the suspender due to the value πx_1: the new ordinate y' of the catenary A'C'B' will be equal to $y(1+\varepsilon)$ *less* the *absolute* value of y or it will be $y(1+\varepsilon)+f(x)$ and $y'=\psi(x)=\varphi(x)+f(x)$ . . . . . (1).
This simple equation characterizes the connection between the two elements of the combination to be examined. The small and variable fraction ε need only be considered in a calculation of correction. The moment of flexure $M x_1$ for $x=x_1$ can be expressed in two ways.

a.) It is equal to

$$\text{E.I.}\frac{d^2y}{dx^2}=\text{E.I.}f''(x)$$

in accordance with Euler's fundamental equation.

b.) Taking the point for which $x=x_1$ as fulcrum, it is equal to the moment of all exterior forces acting on $O'x_1$, care being taken that in agreement with the form of the curve, the moment so found has the same sign as $\frac{d^2y}{dx^2}$. Consequently the moment is

$$Mx_1=R_1.x_1-W_1(x_1-l_1)-W_{11}(x_1-l_{11})-\ldots-(p+k).\frac{x_1^2}{2}+\int_o^{x_1}[\pi_x(x_1-x).dx]$$

a.) and *b.*) are equal, hence there is already found the relation looked for, which only needs simplification. As regards the integration *b.*), the differential quotient of $\psi(x)\times Q$ represents the load carried by the cable. The differential quotient of the product or $Q.\frac{d^2\psi(x)}{dx^2}$ is the intensity π_x by which the shearing force changes at x. Hence:

$$\pi_x=Q\frac{d^2\psi(x)}{dx^2}=Q.\left\{\frac{2.H(1+\varepsilon)}{b^2}+f''(x)\right\}$$

which is an absolute value. The integral in *b.*)

$$\int_o^{x_1}[\pi_x(x_1-x).dx]=x_1\int_o^{x_1}\pi_x dx-\int_o^{x_1}[x.\pi_x.dx] \text{ becomes } =Q.x_1.\int_o^{x_1}\left\{\frac{2.H.(1+\varepsilon)}{b^2}+f''(x)\right\}dx-Q.\int_o^{x_1}x\left\{\frac{2.H.(1+\varepsilon)}{b^2}+f''(x)\right\}dx$$

and omitting $(1+\varepsilon)$ which is tied to H and simplifying

$$=Q.\frac{x_1^2.H}{b^2}+Q.x_1.\int_o^{x_1}f''(x)dx-Q\left\{f'(x).x\right\}_o^{x_1}+Q.\int_o^{x_1}f'(x).dx.$$

$$=Q.\frac{x_1^2.H}{b^2}+Q.x_1.f'(x_1)-Q.x_1.f'(x_1)+Q.f(x_1)-Q.f(x_0)$$

where $f(x_0)$ is a constant value and two other constants have disappeared. Finally the integral is obtained

$$=Q.x_1^2.\frac{H}{b^2}+Q.f(x_1)+\text{constant.}$$

This value introduced into eq. *b.*) the values *a.*) and *b.*) furnish for M_{x_1}, at the point where the abscissa is x_1, the value

$$\text{E.I.}\frac{d^2y}{dx^2}=R_1.x_1-W_1(x_1-l_1)-W_{11}(x_1-l_{11})-W_{111}(x_1-l_{111})-\ldots-(p+k)\frac{x^2}{2}+Q.x_1^2.\frac{H}{b^2}+Q.f(x_1)-Q.f(x_0)$$

Now all x have disappeared and M_{x_1} is only expressed by x_1, so that simply returning to x and after two differentiations the fundamental equation

$$\text{E.I.}\frac{d^4y}{dx^4}=-(p+k)+\frac{2.Q.H}{b^2}+Q.\frac{d^2y}{dx^2}.\ (2.)$$

is obtained.

This equation can be simplified in appearance by putting

$$\left.\begin{aligned}&\text{E.I}=Q.t^2 \text{ and}\\ &z=\left(\frac{d^2y}{dx^2}+\frac{2.H}{b^2}+\frac{p+k}{Q}\right)\end{aligned}\right\}\ldots(3.)$$

whereupon the equation follows

$$\frac{d^2z}{dx^2}-\frac{z}{t^2}=o$$

which integrated leads to the expression

$$z=A.e^{\frac{x}{t}}+B.e^{-\frac{x}{t}}$$

where $e=2.7182818$, or

$$\frac{d^2y}{dx^2}=A.e^{\frac{x}{t}}+B.e^{-\frac{x}{t}}+\left(\frac{p+k}{Q}-\frac{2\ H}{b^2}\right)$$

$$\frac{dy}{dx}=t.\mathrm{A}.e^{\frac{x}{t}}-t.\mathrm{B}.e^{-\frac{x}{t}}+\left(\frac{p+k}{\mathrm{Q}}-\frac{2\mathrm{H}}{b^2}\right).x+\mathrm{C}$$

$$y=t.^2\mathrm{A}.e^{\frac{x}{t}}+t.^2\mathrm{B}.e^{-\frac{x}{t}}+$$

$$\left(\frac{p+k}{\mathrm{Q}}-\frac{2.\mathrm{H}}{b^2}\right).\frac{x^2}{2}+\mathrm{C}.x+\mathrm{D}\ \ .\ .\ .\ (4.)$$

which is the equation $f_1(x)$ for the branch from $x=o$ to $x=z$; A, B, C, D and t are unknown constants which must suit, firstly the general conditions of rigid bodies in equilibrium, and secondly the end conditions of the system. In the following pages the loads W are left off and only p and k are retained.

For the part of the curve from $x=z$ to $x=2b$ a similar equation is obtained, O′ being kept as origin

$$f_{11}(x)=y_{11}=t.^2\alpha.e^{\frac{2b-x}{t}}+t.^2\beta.e^{-\frac{2b-x}{t}}$$

$$+\left(\frac{k}{\mathrm{Q}}-\frac{2\mathrm{H}}{b^2}\right)\frac{(2b-x^2)}{2}+px+\delta\ \ .\ .\ (4a)$$

where α, β, γ and δ are new constant values.

The general conditions of equilibrium of rigid bodies, here applied, require that the algebraic sum of the moments of all the forces acting thereon, including reactions, for any point must be equal to zero, and that also the algebraic sum of the parallel weights and reactions be equal to zero. The moments taken for O′ and O″ include the second condition.

Taking the fulcrum O″ the moment of the weights is M_0''. At A′ the reaction of the cable is $-\mathrm{Q}.\psi'(o)$ [negative sign because $\psi'(o)$ is negative, and reaction positive]. The reaction of the beam at O′ is R_1, and the moments $\pm\mathrm{Q}.h$ disappearing, $\mathrm{M}_0''=2b[\mathrm{R}_1-\mathrm{Q}.\psi'(o)]$. For the value $\mathrm{R}_1=\mathrm{E.I.}\frac{d^3y}{dx^3}$, x at O′ being O, the value $\mathrm{E.I.}\left(\frac{\mathrm{A}}{t}-\frac{\mathrm{B}}{t}\right)$ is obtained from eq. (4.).

For $\psi(o)$ is got $\varphi'(o)+f'(o)$, or consequently

$$\frac{\mathrm{M}_0''}{2b}=\frac{\mathrm{E.I}}{t}(\mathrm{A-B})-\mathrm{Q.C}-\mathrm{Q}.t(\mathrm{A-B})+\frac{2.\mathrm{H.Q}}{b}$$

and since $\mathrm{E.I}=t.^2\mathrm{Q}$,

$$\frac{\mathrm{M}_0''}{2b}=-\mathrm{Q.C}+\frac{2.\mathrm{H.Q}}{b_1}$$

hence

$$\mathrm{C}=\frac{2\mathrm{H}}{b}-\frac{\mathrm{M}_0''}{2b.\mathrm{Q}}\ \text{and}\ p=\frac{2.\mathrm{H}}{b}-\frac{\mathrm{M}_0}{2b.\mathrm{Q}}\ .\ (5.)$$

The assumption of certain end conditions of the system may now be proceeded with:

The beam O′O″ is supposed to be without end moments and to be provided for ± end reactions R. Hence for

$$\left.\begin{array}{l} x=o,\mathrm{M}_x=o,\ \mathrm{A+B}=-\\ \qquad\left\{\frac{p+k}{\mathrm{Q}}-\frac{2.\mathrm{H}}{b^2}\right\}=\mathrm{C}_1\\ x=2b,\ \mathrm{M}_{2b}=o,\ \alpha+\beta=-\\ \qquad\left\{\frac{k}{\mathrm{Q}}-\frac{2.\mathrm{H}}{b^2}\right\}=\mathrm{C}_{11}\end{array}\right\}\ .\ (6.)$$

where C_1 and C_{11} are introduced for the sake of brevity.

To obtain further conditions for the determination of constants it is now desirable to consider that the two branches of the elastic curve must be identical for $x=z$. This condition requires that:

$$y_1=y_{11};\ f_1'(z)=f_{11}'(z);\ f_1''(z)=f_{11}''(z);\ f_1'''(z)=f_{11}'''(z)$$

or that the ordinates, the tangents, the moments and the shearing forces must be equal for $x=z$. (7.)

Hence

$$(a.)\ \ t.^2\mathrm{A}.e^{\frac{z}{t}}+t.^2\mathrm{B}.e^{-\frac{z}{t}}-\mathrm{C}_1.\frac{z^2}{2}+\mathrm{C}.z+\mathrm{D}=$$

$$t.^2\alpha.e^{\frac{2b-z}{t}}+t.^2\beta.e^{-\frac{2b-z}{t}}-\mathrm{C}_{11}\frac{(2b-z)^2}{2}+\gamma(2b-z)+\delta.$$

$$(b.)\ \ t.\mathrm{A}.e^{\frac{z}{t}}-t.\mathrm{B}.e^{-\frac{z}{t}}-\mathrm{C}_1.z+\mathrm{C}=-$$

$$t.\alpha.e^{\frac{2b-z}{t}}+t.\beta.e^{-\frac{2b-z}{t}}+\mathrm{C}_{11}.(2b-z)-\gamma$$

$$(c.)\ \ \mathrm{A}.e^{\frac{z}{t}}+\mathrm{B}.e^{-\frac{z}{t}}-\mathrm{C}_1$$

$$=\alpha.e^{\frac{2b-z}{t}}+\beta.e^{-\frac{2b-z}{t}}-\mathrm{C}_{11}$$

$$(d.)\ \ \frac{\mathrm{A}}{t}e^{\frac{z}{t}}-\frac{\mathrm{B}}{t}e^{-\frac{z}{t}}$$

$$=-\alpha.e^{\frac{2b-z}{t}}+\beta.e^{-\frac{2b-z}{t}}$$

From $(a.)$ and $(c.)$ results

$$D-\delta=\frac{p.t^2}{Q} \quad . \quad . \quad . \quad . \quad (8.)$$

Since D and δ only appear in (a.) nothing further about them is known for the present. But the values y for O′ and O″ are found $=t^2(A+B)+D$ and $t^2(a+\beta)+\delta$ and their difference $y_0-y_{2b}=t^2(C_1-C_{11})+p.\frac{t^2}{Q}=$ nothing, or the end deflections must be equally great. Also A′ and B′ must be on a level. On account, therefore, of the extended suspenders and compressed towers, a little freedom must be given at O′ and O″ so that under one-sided loads a small distortion will precede the regular action of the forces, one of the points O′ and O″ being a little higher than the other. The towers need not support exactly at A and B, they can stand a little behind, and the end pieces of the cables can be arranged to accommodate the distortion mentioned.

From (b.) and (d.) follows $-z.C_1+C=C_{11}(2b-z)-y$ which does not give any new information, so that really there are only three equations instead of four. From (c.) and (d.) can be obtained:

$$a.\left(e^{\frac{2b}{t}}-e^{-\frac{2b}{t}}\right)=C_1-C_{11}.e^{-\frac{2b}{t}}+\frac{p}{2Q}\left(e^{\frac{z}{t}}+e^{-\frac{z}{t}}\right)$$

$$\beta.\left(e^{\frac{2b}{t}}-e^{-\frac{2b}{t}}\right)=-C_1+C_{11}.e^{\frac{2b}{t}}-\frac{p}{2Q}\left(e^{\frac{z}{t}}+e^{-\frac{z}{t}}\right)$$

$$A.\left(e^{\frac{2b}{t}}-e^{-\frac{2b}{t}}\right)=C_{11}-C_1.e^{-\frac{2b}{t}}-\frac{p}{2Q}\left(e^{\frac{2b-z}{t}}+e^{-\frac{2b-z}{t}}\right) \quad (10.)$$

$$B.\left(e^{\frac{2b}{t}}-e^{-\frac{2b}{t}}\right)=-C_{11}+C_1.e^{\frac{2b}{t}}+\frac{p}{2Q}\left(e^{\frac{2b-z}{t}}+e^{-\frac{2b-z}{t}}\right)$$

and also

$$A.e^{\frac{z}{t}}=\beta.e^{-\frac{2b-z}{t}}-\frac{p}{2Q} \text{ and}$$

$$B.e^{-\frac{z}{t}}=a.e^{\frac{2b-z}{t}}\frac{p}{2Q} \quad . \quad . \quad (9.)$$

from which (10.) were derived with utilization of (6.)

In order to determine Q and t another condition is needed. This condition consists of the known length of the cable which, under the strains containing analytically only the unknown quantity ″Q, would stretch in a degree which can be expressed by an equation.

The new length, also expressed by an integral, would have to be equal to the original length plus the extension, the analytical expression of the whole condition is very complex. But by making a hinge in the center of the beam, and thus also avoiding strains and intricate calculations due to changes of temperature all complication is avoided.

Already before Koepke, in 1860, made this observation, a Prussian Government Commission reported that the trusses of the Niagara Railroad Suspension bridge, to avoid considerable additions to the strains, should be interrupted in the center. (*See* Erbkam's Zeitschrift fur Bauwesen, Berlin).

Supposing now that $z \mathrel{\overline{\overline{<}}} b$ and that there is a hinge in the middle, there must become $M_{x=b}=0$ or $a.e^{\frac{b}{t}}+\beta.e^{-\frac{b}{t}}-C_{11}=0$, which with (10.) gives the equation (11.)

$$(1-e^{\frac{b}{t}})(1-e^{-\frac{b}{t}}).2.C_{11}.Q=p.$$

$$(1-e^{\frac{z}{t}})\,(1-e^{-\frac{z}{t}}) \quad . \quad . \quad . \quad (12.)$$

so that for $z=b$, or in case that the bridge is half loaded $2.Q.C_{11}=p$, $Q=\left(k+\frac{p}{2}\right)\frac{b^2}{2H}$,

$C_{11}=-C_1=\frac{p.\ H.}{b^2.(k+p_2)}$ $a=-A$: $\beta=-B$. . . . . . . (13.)

Hence, if the bridge is half filled with uniform load p, the cables—as far as Q is concerned—are strained as if the moving load $p\ b$ were spread over the whole

span with the intensity p_2 *and* as if the cables were still hanging in parabolic curves.

But it does not follow that their form is parabolic. It results from (13.) that the equations for the moments of both halves of the beam are identical, but of opposite signs.

An interesting quality of the hinged beam, when half loaded, is this. According to (13.) y_1 and y_{11} for symmetrical points x_1 and $2\,b-x_1$ by adding give

$$y_1+y_{11}=D+\delta=\text{a constant value.}$$

It also follows from (6), (10) and (13) that under full load K, or full load $(p+k)$, C_1 is equal to C_{11} and that $\alpha=\beta=A=B$ $=$zero, and that all moments become zero. There is also $M_0''=M_0'$ or $C=\gamma$ $=o$ and only D remains$=\delta$.

Be it remembered that thus far the extension of the cables was not considered. They will stretch, the hinge will sink, and the beam not being made for the nearly parabolic curvature natural to the cables, there will result small moments and small shearing forces and a small change of form of the cables, which originally was made parabolic by means of adjustable suspenders. In order to determine those strains, the length of the cable must still be considered, hinges, notwithstanding. H will increase, there will be a sudden tangential break in the middle of the cable, Q will decrease, and the influence of $(1+\varepsilon)$ will have to be considered.

Equation (10), (11) and (12) give these formulæ.

$$\alpha=C_{11}.\frac{1-e^{-\frac{b}{t}}}{e^{\frac{b}{t}}-e^{-\frac{b}{t}}};\quad \beta=C_{11}.\frac{e^{\frac{b}{t}}-1}{e^{\frac{b}{t}}-e^{-\frac{b}{t}}};$$

$$A=C_{11}.\frac{e^{-\frac{b}{t}}-e^{-\frac{2b}{t}}}{e^{\frac{b}{t}}-e^{-\frac{2b}{t}}}-\frac{p}{2Q}.e^{-\frac{z}{t}};$$

$$B=C.\frac{e^{\frac{2b}{t}}-e^{\frac{b}{t}}}{e^{\frac{b}{t}}-e^{-\frac{b}{t}}}-\frac{p}{2Q}.e^{\frac{z}{t}}\quad . \quad (14)$$

The discussion of eq. (13.) leads to the limiting values of Q. For $z=o$ it is $\frac{k.b^2}{2.H}$ for $z=b$ it is $\frac{(k+p)}{2.H}.b^2$. If the load p progresses beyond the hinge the problem can be treated as if the whole bridge were loaded with $2b(p+k)$ and as if the movable load p were negative, so that for $z=2b$ the value Q becomes $(k+p)\frac{b^2}{2.H}$. For intermediate values Q equation (13.) can be written thus:

$$\frac{y}{t}=\frac{e^{\frac{z}{t}}+e^{-\frac{z}{t}}}{2}=1+\left(\frac{e^{\frac{b}{t}}+e^{-\frac{b}{t}}}{2}-1\right).\frac{p}{2.C_{11}.Q}$$

It is well known that $t.\frac{e^{\frac{z}{t}}+e^{-\frac{z}{t}}}{2}$ is the ordinate p of a catenary proper, where t is the ordinate for $z=o$. The left side of the equation consequently represents $\frac{y}{t}$, and the right side is known, Q being simply assumed. The solution of this equation gives

$$\frac{z}{t}=\text{log. nat.}\left(\frac{y}{t}\pm\sqrt{\frac{y^2}{t^2}-1}\right)$$

and for common logarithms

$$\text{log. } z=\text{log. } t+0{,}362216+$$
$$\text{log. log.}\left(\frac{y}{t}\pm\sqrt{\frac{y^2}{t^2}-1}\right)\quad . \quad . \quad . \quad (15.)$$

so that for any Q chosen between

$$\frac{b^2.k}{2.H},\ \frac{b^2.}{2.H}(k+p^2),\ \frac{b^2}{2.H}.(k+p)$$

the corresponding z „ „ „ o, b and $2b$ can be found, so that also t and all other constants are known. The series of z and of other values found should be represented graphically.

All formulæ developed contain the *assumed* value I, which, in fact, is just the quantity to be found.

Differing from the *common theory* of stiffened suspension bridges, it depends, like the moments, etc., on the *permanent* load $2\,b.$ K.

But several examples for varying proportions of $\frac{P}{k}$ and $\frac{H}{2b}$ having been calcu-

lated, certain values of I will be found which can be used towards, at first, approximately assuming I in case of a special project. Calculations of correction are then to follow. The way having been shown in principle, the labor of developing secondary problems is not intended to be done here.

High strains (use of excellent material, excellency of detail design, and superior workmanship combined) are accompanied with great deflections, which, in combination with plate cable curves, reduce the moments of flexure.

It may be desired to build a roadway bridge, which rarely, if ever, will be strained to the limit of the specification. Here the principle of the *stable equilibrium* of the catenary, which has saved so many a weakly-designed suspension bridge becomes useful. For the *limit of flexibility* is indicated, if not already by the chord material *required* on account of wind, by the *greatest admissible grade* of the floor at O′ and O″. This grade at O′ is $a_1 = t\,(A-B)+C$ and at O″ it is $a_{11} = t\,(-a+\beta)-\varphi$. These equations lead to tolerably simple (16) formulæ, if a is only chosen for the case of a half-loaded bridge, because, for this supposition $Q=\frac{b^2}{2.H}\left(K+\frac{p}{2}\right)$. An initial or positive grade at O′ being arranged, a great a_1 can be admitted and chosen, provided, that if the whole bridge is loaded in summer time, there is no visible sagging. To calculate this *camber* the following formulæ may be found useful:

1) The length of the half parabola is:

$$\overset{b}{\underset{o}{S}}=b\left(1+\frac{2}{3}\frac{H^2}{b^2}-\frac{2}{5}\cdot\frac{H^4}{b^4}+\frac{4}{7}\cdot\frac{H^6}{b^6}-\frac{10}{9}\frac{H^8}{b^8}+\ .\ .\ .\ \right)$$

and for a small variation $\varDelta H$

$$\varDelta\overset{b}{\underset{o}{S}}=\varDelta H.\left(\frac{4}{3}\cdot\frac{H}{b}-\frac{8}{5}\cdot\frac{H^3}{b^3}+\frac{24}{7}\cdot\frac{H^5}{b^5}-\frac{80}{9}\cdot\frac{H^7}{b^7}+\ .\ .\ .\ \right) \qquad (17.)$$

From these formulæ the author has derived others, where ε denotes $\frac{S}{b}-1$ and $\varDelta\varepsilon$ denotes $\frac{\varDelta S}{b}$, viz:

$$2)\ \left(\frac{H}{b}\right)^2=\frac{3}{2}.\varepsilon+\frac{9}{10}.\varepsilon^2-\frac{99}{175}.\varepsilon^3+0{,}255.\varepsilon^4\ldots.$$

$$\varDelta\frac{H}{b}=\varDelta\varepsilon.\frac{b}{H}(0.75+0.9\,\varepsilon-0{,}847.\varepsilon^2+0{,}51.\,\varepsilon^3\ .\ .\ .\ .) \qquad (18.)$$

The deepest point of the cable can be found by solving the equation $\frac{d\psi(x)}{dx}=o.$ The x which satisfied this condition determines the vertical line passing through the center of all forces π_x acting on the cable. The tangents at A′ and B′ drawn to the curve $\psi(x)$ likewise intersect in a point of this gravity line, a property which can be used to fix it. These two tangents where they are intersected by a horizontal line through the deepest point of A′C′B′ give points of the center lines of all those forces π_x acting on the cable, either to the right or to the left of the deepest point of the cable.

It remains still to illustrate by an example the theory now finished.

Given: Span $2b=1600$ feet, $I=180000$ square inches × square feet (depth of girders say 40′.) $H=125'=\frac{\text{Span}}{12{,}8}$. $E=12000$ tons. Permanent load 3 tons $=k$ per lin. foot. Movable load 1 ton $=p$ per lin. foot.

For half loaded bridge

$$z=b=800',\ Q=\frac{3\frac{1}{2}.800^2}{2.125}=8960 \text{ ts.}$$

$$t=491 \text{ ft., } C_{11}=-C_1=\frac{1}{17920};$$

$$A=-a=-\frac{9.2}{10.6}\,;\ B=-\beta=-\frac{47.14}{10^6}.$$

The moment in the centers of the half beams or for $x=\frac{b}{2}$ and $x=\frac{3b}{2}$ are found ± 30800 tons feet, which is at the rate of $\frac{p.b^2}{20{,}3}$. The reactions $\pm$ 166 tons for O′ and O″ are at the rate of $0{,}208.b.p$.

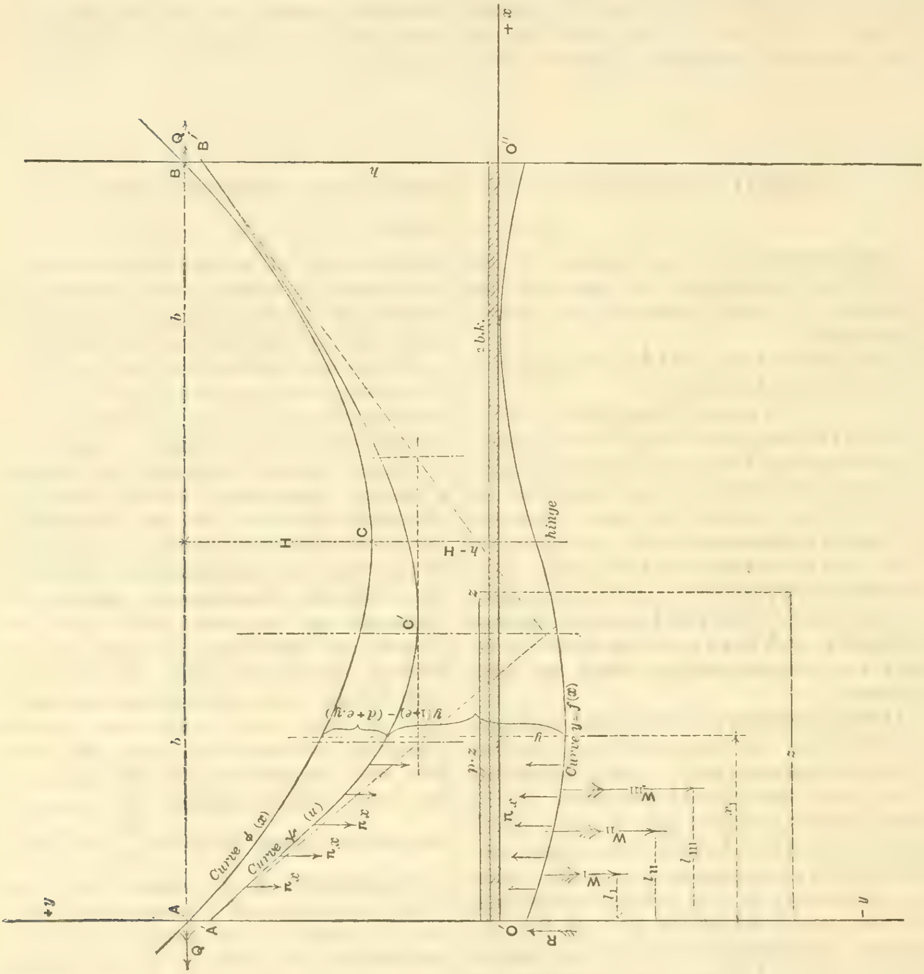
If the bridge had been calculated like a reversed hinged arch, the stiffness due to the change of form of the cables would have been neglected, and if this is termed the common theory the following table may be formed:

	Common theory.	Cables considered.
Reactions	$\pm\frac{pb}{4}=\pm 200$	$\pm\frac{pb}{4{,}81}=\pm 166$ tons.

Advantage of correct theory 17 per cent.
Moments for

$$x=\frac{b}{2} \text{ and } \frac{3b}{2} \pm\frac{pb^2}{16}=\pm 40000,$$

$$\pm\frac{p.b^2}{20{,}8}=\pm 30800.$$



Advantage of correct theory 23 per cent. Strains in chords of beams, tension + pressure tons per square inch 8,888 6,85.

The saving due to distortion of cables is, therefore, not inconsiderable.

If greater flexibility had been desired, the depth of the beam could have been reduced with reduction of I. Shallow girders naturally require greater chord sections.

In case of natural anchorage, H may be reduced with some advantage, leading to a more flexible girder.

The hinge is not the only mechanical arrangement by which the effects of changing temperature can be neutralized.

Fourteen years ago the author, when scientifically occupied with this class of structures, found that continuous ropes led over pulleys attached to cables and floor *continuous self-adjusting suspenders* answer the same purpose. Friction could be considered if desired. Hinged suspension bridges, with beams suspended in this manner, render the theory of reversed hinged arches directly

applicable, and the element of stiffness offered by the cables is really sacrificed. An unhinged beam, with those self-adjusting suspenders, can be built so as to be without negative moments. Its average moment is $0{,}132\ p.b^2$, whilst for hinged reversed arches it is $0.111\ p\ b^2$, where tension and pressure of each beam are added.

To compensate for this loss the average shearing force of the unhinged beam is only $0{,}008\ p\ b$, and for hinged beams it is $0{,}359\ p.\ b.$, in which figures the maximum resulting tension in a member must be considered added to the maximum pressure.

The analysis submitted suggests the possibility *of any degree of stiffness being given* to a suspension bridge.

It is the class of *Partially Stiffened* Regular Suspension Bridges, which the author intended to submit to the consideration of the profession, of which he ventures to hope that—within the practical limits indicated by the premises carefully stated at the beginning—it may become of utility in Bridge Engineering.

WIND PRESSURE ON RAILWAY STRUCTURES.

From "The Engineer."

THE following is the report of the committee appointed to consider the question of wind pressure on railway structures:

To the Right Honorable the President of the Board of Trade.

LONDON, May 20th, 1881.

SIR—In compliance with the instructions from the Board of Trade—a copy of which is given in the appendix—to consider the question of wind pressure on railway structures, and to report to them on the subject, we have made such inquiries and procured such information on the subject referred to as we deemed necessary, and have now the honor to report the conclusions at which we have arrived.

It was necessary in the first instance to ascertain, as accurately as possible from the sources which were accessible to us, what the highest pressures of the wind in this country amount to. With this object we obtained from those observatories and stations where the pressure or velocity of the wind is measured, the statements which we give in the appendix. In order to exhibit the action of the wind during heavy storms, we have also appended lithographic copies of wind diagrams taken by means of self-registering apparatus at Bidston, Glasgow, and Greenwich.

At some of the stations from which we have obtained returns the wind pressures are measured directly by Osler's self-registering anemometers, at others the velocity only of the wind is measured by Robinson's rotating anemometers, the velocity of the wind being taken at three times the velocity of the revolving cups.

For some stations the only published information is the run in miles of the wind during each hour. There can obviously be no more than a general accordance between this and the greatest pressure experienced during the hour. To utilize for our purpose observations taken at stations where the velocity only of the wind is recorded, the records of the Bidston Observatory, where both elements are recorded, have been employed as furnishing a means of connection between the two. In the case of high winds, with which alone we have to deal, it was found that the greatest pressure recorded in an hour was tolerably well proportional to the square of the mean velocity during the hour, and that the empirical formula $\frac{V^2}{100}=P$, where V=maximum run in miles of the wind in any one hour and P=maximum pressure in pounds on the square foot at any time during the storm to which V refers, represented very fairly the greatest pressure as deduced from the mean velocity for an hour. We have accordingly given in the appendix a table calculated from the above formula for deducing maximum pressures from observed velocities.

In addition to the tables obtained from English, Irish, and Scottish stations,

which are those only that are strictly applicable to our inquiry, we give as matter of information a summary of strong winds registered at stations on the Continent and in India.

It will be seen on reference to the tables that the wind pressures vary greatly at different stations. This, no doubt, mainly arises from difference of exposure of the stations to the action of the wind, in consequence of the geographical and local circumstances of their position, but may in some cases be partly caused by differences in the instruments used for measurement. Thus, at Glasgow the highest recorded pressure per square foot is 47 lbs., while at Bidston, near Liverpool, the indicated pressure on one occasion amounted to 90 lbs., and on another occasion to 80 lbs. But the pressures at Bidston seem very abnormal, being much beyond what have been noticed at any of the other stations. The conformation of the ground on which the Bidston Observatory stands is such that the velocity of the wind there might be greatly intensified.

It will be noticed in the lithographs that the records of exceptionally high pressures indicate a very brief duration. From inquiries we have made, we are satisfied that these records are not referable to instrumental error, depending on the recording instrument being carried by its momentum beyond the position of equilibrium, under the wind pressure acting at the moment, but represent a real phenomenon. But whether the exceptionally high velocities to which such pressures are due extend over a considerable space in a lateral direction, or on the other hand are extremely local, is a point on which we have not been able to find experimental evidence.

The differences of the wind pressures observed at different stations led us to consider whether there were any other modes of approximately ascertaining the force of the wind for our purpose. There are many buildings, tall chimneys, ship-building sheds, &c, which probably would not withstand pressures so extreme as those we refer to; but in most cases the contour of the adjoining ground, and the obstruction to wind by adjoining buildings, trees, and other surrounding objects, would render conclusions drawn from such cases unreliable. It occurred, however, to us that some useful information might be drawn from another source, viz., from railways themselves.

It is obvious that on existing railways that have been long in use, a series of experiments, if we may apply such an expression to them, have for many years been carried on, for over them trains have been running at all times of the day and night on high and unsheltered embankments, and along other spaces exposed in many cases to very strong winds. Now, a wind pressure varying from 30 lbs. to 40 lbs. per square foot, is sufficient to overturn the ordinary railway carriages that have been in use during the last 25 or 30 years, and we thought it useful to inquire from the different railway companies for cases where railway carriages have been overturned by the force of the wind. The only cases of this kind that have been brought to our knowledge are appended to this report. From the information thus acquired, from the inquiries we have made, and from the consideration we have given to the subject, we are of opinion that the following rules will sufficiently meet the cases referred to us:

(1) That for railway bridges and viaducts a maximum wind pressure of 56 lbs. per square foot should be assumed for the purpose of calculation.

(2) That where the bridge or viaduct is formed of close girders, and the tops of such girders are as high or higher than the top of a train passing over the bridge, the total wind pressure upon such bridge or viaduct should be ascertained by applying the full pressure of 56 lbs. per square foot to the entire vertical surface of one main girder only. But if the top of a train passing over the bridge is higher than the top of the main girders, the total wind pressure upon such bridge or viaduct should be ascertained, by applying the full pressure of 56 lbs. per square foot to the entire vertical surface, from the bottom of the main girders to the top of the train passing over the bridge.

(3) That where the bridge or viaduct is of the lattice form, or of open construction, the wind pressure upon the outer or windward girder should be ascertained by applying the full pressure of 56 lbs. per square foot, as if the girder were a close girder, from the level of the rails to

the top of a train passing over such bridge or viaduct, and by applying in addition the full pressure of 56 lbs. per square foot to the ascertained vertical area of surface of the ironwork of the same girder, situated below the level of the rails or above the top of a train passing over such bridge or viaduct. The wind pressure upon the inner or leeward girder or girders should be ascertained, by applying a pressure per square foot to the ascertained vertical area of surface of the ironwork of one girder only, situated below the level of the rails or above the top of a train passing over the said bridge or viaduct, according to the following scale, viz:

(*a*) If the surface area of the open spaces does not exceed two-thirds of the whole area included within the outline of the girder, the pressure should be taken at 28 lbs. per square foot.

(*b*) If the surface area of the open spaces lie between two-thirds and three-fourths of the whole area included within the outline of the girder, the pressure should be taken at 42 lbs. per square foot.

(*c*) If the surface area of the open spaces be greater than three-fourths of the whole area included within the outline of the girder, the pressure should be taken at the full pressure of 56 lbs. per square foot.

(4) That the pressure upon arches and the piers of bridges and viaducts should be ascertained as nearly as possible in conformity with the rules above stated.

(5) That in order to ensure a proper margin of safety for bridges and viaducts in respect of the strains caused by wind pressure, they should be made of sufficient strength to withstand a strain of four times the amount due to the pressure calculated by the foregoing rules. And that, for cases where the tendency of the wind to overturn structures is counteracted by gravity alone, a factor of safety of 2 will be sufficient.

With regard to the eighth paragraph of the report of the Select Committee on the North British Railway (Tay Bridge) Bill, to which you have drawn our attention, we beg to observe that where trains run between girders they will generally be sufficiently protected from the wind, the degree of protection afforded by the girders depending upon the extent to which the girders are open or close; where the girders are so open as to afford insufficient protection, or where trains run, as in some cases they may do, on the tops of girders, we assume that the engineer will provide a sufficient parapet, but we are indisposed to go further into detail on this subject, as it might tend to stereotype modes of construction which we think is undesirable.

In conclusion we beg to point out that the velocity of wind, like that of every other moving body, is more or less retarded by friction, and will be affected, therefore, by the character of the surfaces over which it has to pass, which may be rough, smooth, or irregular. It will follow, therefore, that, other things being the same, greater velocities will be retained at higher altitudes than at low ones, the wind at higher altitudes being further removed from retardation by friction.

Though we are of opinion that no bridge or viaduct is likely to be built in such a situation as to expose it to wind pressures equal to those which have been occasionally indicated by the disc on the Bidston Observatory, yet even if that were possible, a bridge or viaduct constructed according to the rules we have given would not be subjected to the strains nearly equal to its theoretical strength.

On the other hand, there will be many structures of small altitude or in sheltered situations which never can be exposed to the wind pressure we have assumed, and where the application of the rules we have given would require modification.

Some modification of the rules may also be required in the case of suspension or other bridges of very large span, but such cases will be of rare occurrence, and we recommend that they should be specially considered when they arise.—

We have the honor to be, Sir, your most obedient servants,

John Hawkshaw,
W. G. Armstrong,
W. H. Barlow,
G. G. Stokes,
W. Yolland.

We, the undersigned, concur in the above report so far as it goes, but we think the following clause should be added, viz:

The evidence before us does not enable us to judge as to the lateral extent of the extremely high pressures occasionally recorded by anemometers, and we think it desirable that experiments should be made to determine the question. If the lateral extent of exceptionally heavy gusts should prove to be very small, it would become a question whether some relaxation might not be permitted in the requirements of this report.

W. G. Armstrong,
G. G. Stokes.

The following is the table above referred to as given in the appendix:

Wind Velocities and Pressures.

Maximum hourly run of the wind in miles.	Maximum pressure in lbs. on the square foot.	Maximum hourly run of the wind in miles.	Maximum pressure in lbs. on the square foot.	Maximum hourly run of the wind in miles.	Maximum pressure in lbs. on the square foot.	Maximum hourly run of the wind in miles.	Maximum pressure in lbs. on the square foot.
40	16·0	56	31.4	71	50·4	86	74·0
41	16 8	57	32·5	72	51·8	87	75·7
42	17·6	58	33·6	73	53·3	88	77·4
43	18·5	59	34·8	74	54·8	89	79 2
44	19·4	60	36·0	75	56·2	90	81·0
45	20·2	61	37 2	76	57·8	91	82·8
46	21·2	62	38·4	77	59·3	92	84·6
47	22·1	63	39·7	78	60·8	93	86·5
48	23·0	64	41·0	79	62·4	94	88·4
49	24·0	65	42·2	80	64·0	95	90.3
50	25 0	66	43·6	81	65·6	96	92·2
51	26·0	67	44·9	82	67·2	97	94·1
52	27·0	68	46·2	83	68·9	98	96·0
53	28·1	69	47·6	84	70·6	99	98·0
54	29·2	70	49 0	85	72·2	100	100·0
55	30·2						

THE PROPOSED INDO-MEDITERRANEAN RAILWAY.

By COMMANDER V. LOVETT CAMERON, C.B., D.C.L., R.N.

From the "Journal of the Royal United Service Institution."

The subject to which we have to turn our attention to-day is one of vast importance to this country, and since the days of General Chesney has never been lost sight of by some among us, although the startling occurrences of modern history have often caused the general ideas of the English nation to be turned in other directions.

The subject of railway communication between the Mediterranean and Persian Gulf has already been discussed here, and it is with feelings of diffidence that I venture to give my opinions on the subject, knowing that every authority hitherto has differed as to the line to be followed, and that I myself agree with no one as to the precise route, though I do in the main idea that it is of the utmost importance to us as a country strategically, commercially, and politically to connect the Persian Gulf and the Mediterranean Sea, by a line of railway which ultimately may be prolonged so as to join our Indian railway system.

I will now describe the country I traveled over, having a special reference to railway construction.

From Cyprus I went by steamer to Beirut, and then when we had collected our baggage animals, we crossed the Lebanon into Cœle Syria, by the French road between Damascus and Beirut. Turning northwards at Shtaura, we went up the valley between the Lebanon and Anti Lebanon to Homs. At Homs we were assured that the best pass between the sea coast and the fertile plains of the interior lay between it and Tripoli. I had, before this, the intention of going

to the sea coast near the mouth of the Nahr el Kebir, and northwards along the coast to Latakia, in order to look for a practicable pass in the mountains; this news determined me to go to Tripoli, and thence, if it proved correct, work back again to Homs.

A Zaptieh was given us as guide, who was said to know the best way, but who took us the shortest way, and the one now followed by many of the caravans; this road, however, did not seem very promising, as the plains which fringed the sea were separated from the plateau we had been crossing by an almost precipitous descent, down which wound a narrow, slippery, zigzag path. But when we arrived at Tripoli, we were told by our Vice-Consul, Monsieur Blanche, who has spent many years there, and is well acquainted with the topography of the surrounding country, that we had been brought the shortest line, but not the best, as by going round a little way and following the line of the old Roman road, we should find an easy route from the coast plains into the interior.

Tripoli is now a place of less importance than either Beirut or Iskanderun, but her position at the mouth of the most practicable pass into the interior insures for her a most important future. She was in ancient times a larger and richer town than any of her modern rivals, whilst her predecessors, Arvad of the Phœnicians, now the desert Island of Ruad, was a competitor with Tyre.

During all times but the most modern, the route which we took from Tripoli back to Homs was the most important of all those between the coast line and the interior. The Egyptians in their wars against the Hittites made use of it, and the foundations of Kalaat Ibn Hosn, a fortress which has played a part in many a forgotten war and campaign, show traces of their handiwork. As the Egyptians invaded the Hittites before the days of Moses, this position has long been regarded as one of importance. The two wadys by which the higher level is reached join together very curiously in the center of their length; and whilst below this junction one is too narrow and has its sides too precipitous to be of use for carrying a road up it, above this point it is wide and easily ascended, whilst precisely the reverse is the case with the other.

The Romans, in forming their road into the interior, took advantage of this peculiarity, and in many places their ancient causeway might be utilized in the construction of a railroad, although, of course, in some cases the gradients would be too steep. From the watershed (highest point 1,100 feet) at the head of these wadys a gentle slope leads to the fertile plain of the Lesser Bukéa (level 720 feet); this crossed, a second line of hills has to be crossed, but for only about 3 miles did any difficulty present itself, and that might be easily overcome. In crossing this plain, 180 feet was risen almost imperceptibly, and then for the first 3 miles to Hadeedy, 300 feet more would have to be ascended, or a gradient of 1 in 60. From Hadeedy 350 feet more would have to be risen to arrive at the highest point between Homs and the sea. Here the steepest gradient would not be above 1 in 80. Some old Roman bridges show that once there were rivers running on this piece towards the Lake of Homs, and some provision would have to be made for the flood waters, and at one place near Jisr Achan (Bridge of Achan) it might be better to cross a small valley by an embankment and cutting instead of making a *detour* to avoid it, or by using heavy gradients. From the highest point a very easy slope brings the line down to the Orontes, which here can be easily crossed, and the town of Homs is at once reached. Homs is even now a place of considerable importance, and is well situated as being a point whence level roads diverge towards Damascus, Baalbec, and Hamath.

Homs is also on the direct route to Palmyra if at any time the Palmyrene Railway should be decided upon, and, therefore, is destined to be one day a great junction station.

Any body of troops concentrated at or nears Homs, and having railway communication with Tripoli, would command the whole of Syria behind the ranges of the Lebanon; grain, cattle, and sheep are abundant, and addition to the water supplied by the Orontes and its affluents, wells of no great depth (about 30 or 40 feet) might be easily made where required.

If ever the Suez Canal is to be threat-

ened by an army marching from Asiatic Turkey, that army would have to pass through the districts around Homs, and a force there might easily be reinforced from Cyprus if the railway to the coast be constructed.

There are the remains of large barracks which were constructed by the Egyptians during their occupancy of the country, and although now destitute of doors and windows, and looking in a ruinous and dilapidated condition, still they were so well built originally that they might easily be put in repair.

The whole country is so flat that there would be no difficulty in moving troops in any direction, and if wheeled vehicles were imported, there is nothing to prevent their being used. Mules, camels, and horses are plentiful, and if the friendship of the Aneyzeh Arabs were secured, an almost unlimited number of camels might be procured at a very cheap rate.

From Homs to Hamath, with the exception of crossing the valley of the Orontes, at Rusta, there is scarcely any work to be done, and the whole country is fertile, and, under a settled and just Government, the population, at present huddled together miserably in the towns, could be profitably employed in agriculture.

The Orontes at Rusta runs in the bottom of a gully about 120 feet below the general level of the plain; here was once, as at all other important points, a Roman fortress which defended the passage of the river. The southern side of this gully widens out and slopes gradually just to the west of the village, and an easy gradient would bring us down the first 60 feet from whence a viaduct of about 300 yards in length would take us to the north of the river. Here the line might either wind round the curve of the bluff, or a cutting 60 feet deep at the commencement, running down to nothing at the end, be made for a distance of half a mile.

After this, as far as Hamath, the line might be laid on the surface, only leveling, ballasting and drainage having to be attended to.

At Hamath, the Orontes would have to be crossed again for the third and last time, but as its valley widens out around the town, no difficulty would be met with here beyond that of bridging the stream.

Hamath is one of the most ancient towns now existing in the world, and is constantly mentioned in the Pentateuch and other historical portions of the Bible. When we were there, it was crowded with Circassians who had been deported from European Turkey, and who here, as elsewhere, were a very great source of trouble to the authorities. Here, also, as at Homs, are old barracks which might be repaired, and the khans or caravanserais might also be used for the accommodation of troops. The Aneyzeh have more dealings with the Governor (Mutesarif) of Hamath than they have with the Kaimacan at Homs, and perhaps, therefore, this might be a better spot to collect camels from them. The land which is irrigated by the Orontes is most fertile, and if modern systems of raising and distributing the water were used instead of the cumbrous and clumsy wooden wheels and antiquated aqueducts, it might be enormously increased in extent and productiveness.

At Hamath, the valley of the Orontes is gradually left, and the whole distance thence to Khan Shaykh Khaun is almost perfectly level, the only works necessary being bridges over three river beds, which in the rainy season carry the flood water from the higher land on the east, down to the Orontes.

The khan here is an old building, at all events, dating from the days of the crusaders, and would afford shelter to a large body of men and stores, and would be perfectly defensible against everything except artillery, and the outer walls are so thick and solid that it would require a long-continued fire from the heaviest field guns to breach them. Water is here obtained from wells and is not very good; if the wells were bored deeper the supply would be more abundant and most probably purer. An old stone-lined tank lies outside the south-east corner of the khan, but it has been neglected and is now useless; doubtless it might easily be repaired, and if care were taken, every year's rains would fill it and afford a supply for the months of drought.

At Khan Shaykh Khaun, the hills which form the edge of another plateau are reached, and an easy ascent leads to

their summit. An average gradient of 1 in 120 would, by following the curves of the hills, bring the line to the highest point between Khan Shaykh Khaun and Marah. Marah, which lies in a slight valley, may be reached by a gradient averaging 1 in 250, and thence again the level of the plateau may be equally easily reached. Though anciently all this country was covered with large and wealthy towns, it is now quite bare and deserted. Immediately round Marah are vineyards, and wheat is cultivated, but the people live in dread of the Bedouins, and dare not go far afield. The khan here is even larger than that at Shaykh Khaun and was repaired by Ibraham Pasha. It might easily be converted into very good barracks, and there are the ruins of an old Genoese castle which might also be utilized. The town itself is mean and miserable, though if the Kaimacan was to be believed it was very prosperous and exported large quantities of grain and raisins.

Some idea of the want of order that exists about here may be drawn from the fact that some Bedouins made a dash right into the khan, and drove off some mules, though their owners outnumbered them by more than two to one, and even when the Zaptieh were appealed to, they refused to follow the raiders.

From Marah a slight rise brings one again on to the higher level, which if it were not for the purpose of collecting the traffic of the town and district, need not have been quitted; thence to close to Aleppo, the whole road is practically a level one. Around Marah are an enormous number of ruins, dating from the latter days of the Byzantine Empire; these show that once the whole of this country was densely populated; and as we went along we saw several small towns and villages besides the important one of Idlib, and numerous villages. The smaller towns and the villages are now, or were when we passed by, greatly troubled by the Arabs. Some years ago the Arabs of the desert used to levy blackmail from their inhabitants, who are also Arabs, and in return used to prevent the Turkish tax gatherers from collecting the taxes. The then Wali of Aleppo, in order to meet this difficulty, organized a corps of rifles, mounted on mules, who were able to keep the Bedouins in check, and the peasantry paid taxes to the Turks instead of blackmail to the Aneyzeh. The needs of the Porte during the Russo-Turkish war led to this corps being sent as infantry to join the army in the field, and now the Aneyzeh have extorted blackmail, and what they are pleased to consider the arrears, and also allow the taxes to be collected, the peasantry, therefore, are in greater straits than ever they were. At Khan Tomaun, near Aleppo, the caravan road from the south leads over some stony hills, but by following the valley of the River Halep, an easy and level road may be found.

Aleppo in ancient days was the principal emporium of Eastern commerce, and at present it is calculated that 80,000 camels are employed in her carrying trade, 10,000 of which are to be found between Aleppo and Iskanderun.

The barracks built by Ibrahim Pasha are capable of holding 10,000 troops, and there is a very fair military hospital which, at the time of my visit, was occupied by deported Circassians. The khans, which are numerous and spacious, would also lodge large numbers of men, and there are many large houses belonging to merchants and private individuals, as well as arcaded bazaars, which might all be utilized in the case of necessity. The citadel is in a very ruinous condition, but a great portion might be roughly repaired and rendered of use.

Owing to the commercial importance of Aleppo, and the number of pack animals constantly passing through, transport and supplies for a very considerable body of men might easily be collected there, and as it commands the routes to Syria, Iskanderun, Aintab, and those of the Euphrates Valley and Mosul, it will always be a place of the greatest strategical value.

If the line were commenced, as most people consider it should be, at Seleucia or Iskanderun, very much greater engineering difficulties would have to be encountered than by the route I have traced out, the fertile regions around Homs, Hamath, and Idlib would be left unprovided for, and if an army from the north or east had managed to possess itself of Aleppo, there would be no means of opposing its advance on the Suez Canal, through Syria and Palestine, whereas, even if Aleppo should be in an enemy's hands, we could by the line I advocate pour in troops and supplies from Tripoli

on Homs, and there make a second stand to cover our great waterway to the East.

Proceeding eastwards from Aleppo as far as Tedif, a small town, four miles from Bab, where there are barracks, which might be made to contain 2,000 men, the ground is quite level, and then some gentle undulations would have to be crossed before arriving at Hierapolis (Mombedj). Here are settled some Arabs, who claim to belong to the great Aneyzeh tribe, and who are especially friendly to the English, as are all the inhabitants of the surrounding country, except some of the deported Circassians, who are enemies to every one, including themselves. These Arabs would be of use in constructing a railway, and from them and their relations in the desert might be gathered a number of hardy horsemen, who, with a little training and teaching, might render invaluable service in war time as scouts and also for harassing the convoys of an enemy.

From Mombedj the most level line to the Euphrates would be to the embouchure of the Nahr Sadshur, where a bridge might be easily constructed at a camel ford; the Romans indeed bridged the river a little lower down and where the water is deeper, and I can conceive no difficulty to a modern engineer in constructing a bridge across a river where the greatest depth of water would be four feet, and where the foundations of many of the piers might be made on islands and shoals which are dry for the greater portion of the year.

When the river is crossed, some insignificant hills have to be passed through, and then the plain, level as a billiard table, on which are situated Haran and Urfa, is reached. Haran is now only inhabited by a few sedentary Arabs, but there are the remains of the Roman camps and also of the castle, church, and fortifications built by the Crusaders under Baldwin and his successors, Counts of Urfa.

Urfa, itself, is a place by which a great deal of trade passes, being situated at the foot of the hills over which the road to Aleppo via Bir-ed-jik runs, and most of the traffic between Aleppo and Mosul and Diarbekr passes by. Monsieur Martin, the French Vice-Consul, who owns a considerable amount of land in the neighborhood, and also buys grain in large quantities, told me he often dispatched over 600 camels to the coast, loaded with wheat, in one day, and sometimes had sent off 1,200 in one caravan.

There are some very good barracks in good repair, which would hold three or four battalions of infantry, and the khans and the Government buildings at Serai might also be utilized. The old walls round the town are, in many places, in fair condition, and on the sides towards the plain there is a deep ditch, almost a ravine. The place might easily be made defensible against troops unprovided with siege artillery.

Crossing the plain from Urfa, and keeping under the mountains which form the boundary between the Northern Mesopotamian Plain and the high lands of Armenia and Kurdistan, we should for a short distance have to pass through low and rounded hills, where some slight works might be necessary; but once these hills are passed, an unbroken plain extends away to the east of Nisibin.

At the southern end of the Karaja Dagh there is a break in the line of mountains, and an easy road or a branch line, might be made to the important city of Diarbekr.

Diarbekr is still enclosed within walls, of what date it is difficult to say, but the curious way in which carved and sculptured stones of different periods are placed in juxtaposition tells something of the many vicissitudes through which the city has passed.

Of old the capital of Armenia, it even now is one of the most important points in these regions. When the railway through Anatolia from the Bosphorus is constructed, Diarbekr is sure to be one of the places through which it will pass. It commands the passages of the Tigris, and an army corps having its head-quarters at Diarbekr ought to command the upper waters of both the Tigris and Euphrates, and be able to prevent an army advancing from Kars and Erzeroum, on Syria or Baghdad, from utilizing these rivers for the purposes of transport. Diarbekr is even of more account in the present day because of her bridge than because of her walls and ancient churches and mosques. The same story may be read in the stones of the bridge as in those of the walls, and its earliest parts

most probably date from before the Christian era.

Returning to our main line, we soon pass under the famous town of Mardin, perched up in the mountainous crags that overhang the plain like the eyrie of an eagle. Mardin is the one place which held out successfully against the elsewhere-victorious arms of Timour.

From the ruins of the old citadel, a most extensive view is obtainable, and the range of the Sinjar hills which extend from Mosul to near Palmyra for some of the distance, being known as the Abdul Aziz Mountains, bound the southern horizon. Mardin dominating the plain in the manner it does, and being easily capable of being rendered impregnable, would form a most important position in the defence of the line, and no army advancing from the east could dare to pass such a post unless it were masked by a force far superior to its garrison; and, even then, as to surround Mardin is almost impossible, a daring body of cavalry having it as their *point d'appui* might so harass the communications of troops advancing either from the northeast or east, as to cause serious anxiety to their commanders.

South of Mardin, around Ras el Ain, are the settlements of a number of Circassians, and beyond them the mountains of Abdul Aziz and the tribes of the desert. Though the Circassians are as bad as their fellow-countrymen elsewhere, still they have some good military qualities, and proper discipline might furnish a valuable body of cavalry. The Arabs, trained in ghazous and raids, and living under the open Heaven, have their perceptive faculties sharpened to the utmost, and would be most invaluable as scouts and to collect information. A man who can steal a mare from the center of the encampment of a rival tribe, though crowded with dogs and cattle, could penetrate into any camp of ordinary soldiers, and bring away in his memory every material detail. On both sides, therefore, the holders of the line, if they also have had the tact necessary to make friends with their neighbors, would be possessed of local means of defence against any enemy.

After leaving Mardin we pass by the towns of Dara and Nisibin, ancient rivals and frontier posts of Imperial Rome, and her constant enemies, the Persians. Both are only now small places of no great importance; but, lying as they do in districts of great fertility and well watered, there is no doubt that they will, when once more in communication with the outer world, show signs of renewed vitality. Though at the time we were at Nisibin there was sickness there, all the surrounding districts were perfectly healthy.

From Nisibin we at first went along a plain, about which were dotted several villages and the ruins of more: many of the latter were quite of recent date; indeed, the Christian Chief of Asmaur told us that ten out of twenty villages inhabited by Chaldean Christians had been destroyed during the previous twelve months. After passing this district around Asmaur, we went across a country once inhabited and covered with towns, but now only affording pasture to the flocks of nomad Kurds or Bedouins, until close to the Tigris just above Mosul.

The whole of the country traversed between Urfa and Mosul was once populous, prosperous and well cultivated, and it is only owing to the apathy of the inhabitants that wells and watercourses have been allowed to become choked up, and forests destroyed, so that what was once a smiling garden is now in parts, for some months of the year, a parched and arid waste.

In the wars between the Parthians or Persians and the Romans, armies, often consisting of over a hundred thousand men, traversed this country in every direction; and if what history relates of luxurious camp-equipage of these ancient warriors be true, they must have been even more hampered and encumbered by non-combatants and beasts of burden than any modern force, and must have everywhere found grain, water, and forage in abundance. As matters are at present, it would be a difficult matter in extra dry seasons to march a force from Urfa to Mosul by this line, though with very little trouble in the construction of wells, there would be no difficulty whatever. As far as I could judge from the appearanae of the land and the dip of the strata, in no place would it be necessary to go deeper than from 70 to 80 feet, and usually a much less distance, before

reaching water; the rock to bore through would be a soft and friable limestone, easily worked, but possessing quite sufficient cohesion for the sides of wells to stand without any artificial means of support.

Of course, if a railway were made here the first thing to be done would be to dig wells. A certain number of laborers might be found on the spot; but a Christian merchant and contractor told me he could place 4,000 families, or about 10,000 working men, at any place or places between Urfa and Mosul, and engage to keep them supplied with food whilst they should be employed. The cost of such labor, including food, should not be more than 1s. 6d. a man a day. The same merchant could also provide, more easily than any one else, carriage for stores and materials, and was so taken with the idea of a railway passing near him, that he said he would take £30,000 in shares, if it ever were made.

Mosul is now surrounded by a wall, which was built a few years ago to protect it from the raids of the Shammar Arabs, but which would be a snare and delusion to its defenders, as it is so badly traced that long stretches of the banquette can be enfiladed by people lying behind the earth thrown up out of the apology of a ditch which surrounds it.

The barracks and Government buildings are outside the town, and might easily be made available for four or five thousand men. On the eastern side of the Tigris the mounds of the ancient Nineveh afford admirable opportunities for the construction of a *tete du pont* to protect the bridge across the river. Mosul commands a route to the northeast and east leading to Teheren and the Caspian, also one to Diarbekr and Jesireh, the great wool mart. Near Jesireh are valuable coal mines which, of course, would prove of great importance, and it would be a question to discuss how best to link them to the line at Mosul.

At Mosul the question arises as to whether it would be better to cross the Tigris there, or continue on its right bank as far as Baghdad. If the river is crossed at Mosul, a very much more difficult country would have to be traversed, two other rivers, the Greater and the Lesser Zab, would have to be crossed, and the railway would be open to raids on it from the east. If the right bank is followed, the railway is protected for its whole length by the river, and easy country is passed through, and the distance is much less than if the railway passed by Erbil and Kerkuk, the only real advantage claimed by those who advocate going to Baghdad from Mosul by the eastern side of the Tigris. Another advantage is claimed, viz., that on the east of the river the railway would be more defended from the Bedouins; but those who raise this chimerical objection forget that any of the railways proposed in those regions would be more or less exposed to such a danger if it did exist, and that the populations to the east of the river are just as likely or more likely than the Arabs, to damage a railway, whilst the Shammar Arabs, through whose districts the line on the right bank would principally run, are at present in alliance with and subsidized by the Turkish Government.

Between Mosul and Baghdad there are no difficulties worthy of the name, and if a railway were constructed and irrigation and agriculture encouraged, the country would once again become densely populated.

Baghdad is one of the largest towns of the Asiatic dominions of the Sultan, and is especially important to us as being so intimately connected with our Indian possessions. As the seat of the Caliphs, Baghdad, and before it the cities of Seleucia and Ctesiphon, was once the center of the civilized world, where learning and arts, commerce and science, had progressed further than they had in Europe, and though it can never be expected that she will regain all her ancient wealth and prosperity, still it may be confidently said that when the principal city of the richest province of Asiatic Turkey is once more in easy communication with the rest of the world, she will again become one of the greatest of marts.

Steamers from Baghdad to Bassorah are now running, two English and six Turkish, besides which the Bombay Marine steamer "Comet" is at the disposal of the Resident. The difficulty of the navigation is such that it is rare indeed that the passage is accomplished in less than four days, and the cost of the double transhipment of goods, and the delays

consequent thereon, would go far to neutralize the advantages gained by the railway. Baghdad can never, therefore, be a terminus—an important station she is and always will remain. As Baghdad cannot be a terminus, where shall we find one? Kweyt and Bassorah have both been proposed; Kweyt is disposed of by the fact that it is on the wrong side of the Persian Gulf, and therefore when (as without any spirit of prophecy it may be asserted will be the case) the line is continued on to meet our Indian system, the Kweyt portion of the line would only serve a very small and very local traffic. Bassorah is debarred by the fact that the land around it is so low and so easily flooded, and is so liable to have channels cut in all sorts of unforeseen directions by these floods, that the construction of a railway to that place would be costly in the extreme, and its maintenance scarcely practicable.

Where, then, shall we look for our temporary terminus? At Abushire, "the father of ports." I know the portion of the line I am now going to advocate has been condemned by Mr. Blunt, who traveled with his wife, Lady Anne, from Baghdad to Abushire (Bushire) by land, and who I have heard assert that it would be utterly useless to construct a railway there, that such a railway would be of no value and never pay. With all respect for Mr. Blunt I venture to differ from him, notwithstanding his personal and local knowledge of this portion of the line. A very large trade between India and Baghdad already exists, and even now people from Bushire go to Baghdad by sea in large numbers. The holy places of the Shiah Mahommedans attract enormous numbers of pilgrims; Samara alone is visited by upwards of 30,000 every year, and many a pious heir brings the corpse of his father to be interred in the holy soil. This traffic, and the trade resulting therefrom, would all be taken by the railway.

He says that the country is uninhabited and uncultivated, but complains of the number of rivers he had to cross. A river properly used in these latitudes means wealth untold to the lucky persons who can avail themselves of its waters, and if these countries are not prosperous at the present moment, it is not from any physical incapability or on account of soil or climate, but on account of the blighting misrule under which they have groaned for centuries. These very rivers, especially the Karun, will be our greatest friends, and will enable us to transport our *matériel* to the required positions at a minimum of time and cost. From Dilam, where the coast should be reached, the shores of the Persian Gulf should be followed as far as Bushire. Here for the time the railway might rest, but as the Eastern Question develops, so will the continuation to Kurachi and a line from Mosul to Herat and Kandahar become more and more plainly necessary. As we have to consider, in a line of this sort, its future developments, and as no doubt it is destined to form one system with the railways of India, it is right and fitting that the guage should be that of the trunk lines of the Indian Empire. One great Power, in her consciousness of the danger of more civilized nations penetrating her shell, has deliberately broken the guage at her frontiers; we should benefit by the lesson thus taught, and in constructing these lines make them more readily available to ourselves, to whom they are of most importance, than to possible rivals.

Bushire and Tripoli, at a comparatively small expenditure, may be made into good harbors and quays, and wharves could easily be constructed at both places so as to avoid the necessity of using cargo boats.

I have thus endeavoured to trace the course of what I hope may be the first section of the Indo-Mediterranean Railway. Instead of its being a rival to the Suez Canal it would prove a most important ally, and would enable us to thwart any attempt on our present lines of communication with India.

By steamers from our now first-class port of Kurachi to Bushire, troops could be conveyed from our Indian possessions to the railways which would place them in the commanding positions in the battlefields of Armenia, there to find themselves met by their brothers in arms arriving from Cyprus and other *places d'armes* in the Mediterranean.

At Cyprus we have a port, Flamagusta, where ironclad ships could lie in perfect safety only six hours distant from the terminus of the railway, and from Cyprus

we could at a moment's notice transport men to stop revolts, barbarities, and atrocities in the greater portion of Asiatic Turkey. The knowledge that we could do so would prevent horrors such as have, in Bulgaria and Roumelia, disgusted the civilized world, and which still leave their poisonous effects behind them.

If the Suez Canal should ever be blocked (a matter by no means difficult of accomplishment), or Egypt and the Canal fall into the possession of a hostile Power, it is to the Indo-Mediterranean Railway that our navy and army would have to look for assistance in maintaining our wonted communications with India, or to recover our control over the great highway for ships.

I fear this has been a long and wearisome paper for those who have listened to it, but railways do not belong to the days of romance and comedy, but to the work-a-day world of the 19th century.

Lieutenant-Colonel BATEMAN CHAMPAIN, R. E.: It seems to me that this question is one of very great importance, and that you, Sir, and every one present will be glad of any light, however small, that can be thrown on the general question raised by the paper to which we have listened. I have twice ridden up the Tigris Valley from Baghdad, once to the Black Sea, and once to the Mediterranean, along a great part of the road that has been so well described by Commander Cameron this afternoon. I merely mention the fact of my having personally visited the country as an excuse for my venturing to say one or two words. If Asia Minor or Mesopotamia belonged to the British Government, I, for one, would consider it our bounden duty to make roads and railways in every direction. I agree with Commander Cameron in thinking that it is one of the richest countries in the world, and every one knows that it has been suffering from ages of misgovernment. But I would, as far as my own opinion goes, protest, as strongly as I have done before, against the idea that the Euphrates Railway or the Tigris Valley Railway would be a really good and sound means of military communication between England and India. Of the two, decidedly I would prefer the Tigris Valley, but I object to the whole scheme, on grounds which I will presently state. I prefer the Tigris route because along the Tigris there are towns and places of commercial importance, whereas on the Euphrates there are none; between Biredjek and Bassorah there is hardly a town or even village of any note. On the other line there are Diarbekr, Mosul, Arbil, Kerkuk, and Baghdad. Those places could, no doubt, well support a small local railway. But if the railway be constructed in a costly manner, as a means of military communication, it would never pay, and consequently I believe would fall into slovenly management, and if ever it were worked would prove a thorough failure. I believe no through traffic would pass over it, even in time of peace, as no merchant in the world could afford to employ that route. Suppose the line were continued as far as the head of the Persian Gulf, the transhipment there and at the other side would cost an enormous amount of money, and seeing how little is paid for freights now-a-days to and from India, it is absurd to suppose that any kind of merchandise would pay the enormous extra cost that would be entailed simply to gain four or five days, and I do not think more would be gained in practice, because the line could not be worked at express speeds. Scarcely any through travelers would use the line. The climate is for three or four months in the year exceedingly pleasant, but any one who knows what it is to be cooped up for three or four days in a railway carriage, even in these temperate climates, will admit that such traveling is exceedingly uncomfortable, even when one has a whole compartment to one's self. But to box up twelve or thirteen soldiers in a third-class carriage, and carry them through that arid, dusty country, would be nearly impossible for nine months of the year. The health and strength of the men would be destroyed unless you could break the journey two or three times, and in that case you would lose all the advantages this route professes to offer. The thermometer has been known to register at Bassorah as much as 126° in the shade—an excess of heat which could not be borne by men packed closely together. On board ship great heat is bad enough, but it is supportable. Life on the Red Sea is, no doubt, at times unpleasant, but to be

cooped up in a railway carriage for a long journey like that, from the Mediterranean to the Persian Gulf, would be intolerable. The worst part of the whole journey to India is thought by many to be the railway from London to Brindisi. Crossing the Isthmus of Suez is also generally looked forward to with a certain amount of distaste, and the bother of disembarking and re embarking at Alexandria and Suez is very great. That being the case, I assert that the line under discussion, unless it is to depend entirely on its local traffic, cannot be pronounced a desirable undertaking. With regard to going down the river from Mosul, I am certainly inclined to think that the left bank is the proper one to follow; you traverse a much richer country and pass through several important towns. As to the Arabs and Kurds, though I have nothing to say against the former, still they are a difficult people to control, and nobody can calculate on making the camel journey from Baghdad to Damascus without being robbed; but, generally speaking, any one can ride, as I and others in this room have done, through the Kurd country without molestation, and that is the line which has always been chosen by the Turkish Government for its post road, its telegraph, &c. Finally, I cannot agree with Commander Cameron in his remarks on the eligibility of Bushire as a port. No ship of any size, drawing more than twelve or fourteen feet of of water, can get within three miles the place.

Mr. Scott Russell, F. R. S.: As I have had the pleasure, I may call it, of examining that country with the view of carrying through it a railway which might be commercially profitable, and which it might be strategically wise for England to promote, I will venture to make a few remarks upon this paper, and I will call attention to the necessity in dealing with this subject of taking three quite distinct views. First, you must consider the relations of this railway to through communication through Europe with the Indian Empire. You must then consider it with special relation to English interests. And, lastly, you must do what is perhaps still more difficult for us to do, consider it with a view to developing the interest and the prosperity of the countries through which it passes. I mention all this, which appears a complicated problem, because I was compelled to think of it, whether I chose or not, in all these different aspects. I was asked by the representatives of several Governments to tell them what, after examination, I considered the best route from Belgrade to the Persian Gulf. As an Englishman my feelings did not stop there. We English have too many friends in India not to think, when there is any talk of such a communication, how we can easily and most conveniently visit our friends in India or have their visits paid to us, and, therefore you will pardon me when I say that I could not make up my mind to stop at the Persian Gulf, and was obliged to go on until I got to Kurachi. I examined that line (1) as a professional *engineer*, who, in his early life, was engaged in the construction of railways, before he began to construct steamships. (2) After that I was obliged to look at it as an *Englishman*; and (3) strategically. I, therefore, went to our most distinguished strategist at the War Office, Sir Henry Storks, who I am sorry to say is now dead. He was good enough to initiate me into all his views with regard to the strategical value, advantages and disadvantages of certain lines of railway in Asia Minor, in Turkey, and in Persia. I discussed with him the whole of these questions, and received from him the best possible advice. You may think it curious that I should have got all this advice from the various States who were interested in this railway, but I tell you that there was no merely mercantile object in view; it was entirely an international object; and for that purpose I made the investigation. I therefore looked at this railway, which is now proposed, and which, if you please, I will call the "Mediterranean and Persian Gulf Railway," in its relation to the great through international communication, and I found that, although it might be very good as a local railway, yet, as an element of through communication, it was not all that I could desire. With regard to Commander Cameron's special line, there are qualities in that line which I have not seen in any others, and they are these: that the line he proposes, although not of high value as a thorough independent line, would, to a considerable extent be a better ad-

junct to a general international communication than any of the other lines I have seen proposed, called "Euphrates Valley Lines." In the system of international railways, which I was compelled to examine, we came to certain points from which we sent off branch lines exactly resembling those laid down by Commander Cameron. Allow me to say, further, that you must consider this international railway in a strategical point of view. I had the advantage of the assistance of one of the most distinguished railway authorities in England, and a Royal Engineer of great eminence, and also of the assistance of an engineer officer in the service of the Turkish Government. I had all the plans and surveys of the different Governments of Europe communicated to me, and where I did not find the surveys satisfactorily executed by other people, I went personally, accompanied by the friends I have named, and examined those districts with reference to their convenience and practicability. I can quite confirm what Commander Cameron has stated, that those ways up to the high level of the central plateaus, which have hitherto been called impracticable and have been avoided, are ways which are easily practicable, just as the line which he has selected is, and can easily be reached and passed by the ordinary standard of steepness of railway which we are accustomed to use in England. Therefore I am satisfied that on no merely engineering ground can Commander Cameron's selection of line be considered at all an impracticable or an unwise one. There is one point, however, on which I rather agree with Colonel Champain, that is, I do not like that line from Mosul to Baghdad. I will not go through my reasons, there are very many, but I do not like it, and I would prefer his Tigris Valley portion for that part of the line, instead of Commander Cameron's. I do not know what his reason is, but my reason for preferring the Tigris is a very strong one. I think it agrees with Colonel Champain's. I would entreat all those officers and members of this Institution, who interest themselves on this subject, not to commit themselves to any particular portion of this or other lines, until they have considered it in the larger view of a through route to India, and I would also entreat them to take another view, which does not seem to have been taken. If in each of those countries you have to pass through, you will begin by laying out a system of railways, designed in the first instance for developing the wealth and commerce of these individual countries, and if you will first of all study the structure of the mountains and the valleys of that country, with a view to the formation of paying local railways, you will find, when you have laid out a systematic group of railways for Turkey and Asia Minor, and for Persia, and when you have systematically connected our Empire in India through Afghanistan and Beloochistan with Persia, that you have almost got a perfect international line which could not be better laid out for an international line than it has been, when you look at the necessities of developing the country through which it passes. If we have performed (as we have done) the great *role* of setting an example to the world of the development of railways, we have also taught this great lesson, that it is folly to lay out bits of railways, and that there is no wisdom in the making of railways but one, namely, to develop an extensive and general plan in the first instance, and then to carry out that larger plan by degrees; after it has been systematically matured; and I say, with regard to these railways, I am satisfied that you can develop the resources of all these countries through which the railway has to pass, in such a manner as to add enormously to the wealth of civilized Europe, and the well-being of the inhabitants, provided you will take all these points into consideration, including the wealth of the country, including our convenience, including strategical defence, and will not commit yourselves to any one branch until you have developed it as a part of the whole. Allow me, in conclusion, to say this one word. I know that if England will take the lead in this matter, there are other States in Europe who will give her cordial assistance in money, in political arrangements, and in support of every kind.

Mr. J. L. Haddan, M.I C.E.: In discussing this admirable paper, as one acquainted with every inch of the ground which Commander Cameron has lately

gone over, I must express my admiration at the remarkable way in which both in his book and lecture, he seems to have picked out the wheat from the chaff; a very difficult task when we consider that, owing to the short period he was in the country, a great deal of his information must have been obtained at second hand. No one, be he the best railway engineer living, which Commander Cameron does not pretend to be, could have hit upon a better line, from a railway surveyor's point of view, than he has done. It is certainly practical, as Mr. Austin's more elaborate surveys demonstrate, but nothing perhaps proves the inelasticity and weakness of ordinary railway construction more than the fact that the easiest line is always sought for, and not one which is necessarily either commercially or strategically the best; in this case the easiest route may be inadmissable, because it does not, in Sir John Adye's opinion, prove itself strategically of value, while in Mr. Andrew's opinion, it is not commercially the best either. The whole of the coast of Syria, between Alexandretta and the Suez Canal, is most formidable for shipping, there being no harbors of any kind; but as if to make up for it, Nature has created from Aleppo on the north down almost to Egypt on the south, an inland highway, along which you could almost drive a coach and four. Part of that natural highway is cleverly followed by Commander Cameron, viz., from Homs to Aleppo, and he thus taps the best part of the country. With reference to strategy, I beg to point out an important change in the question, one which the older advocates of the Euphrates Valley Railway, probably from long habit of one line of thought, have not noticed. They seem to forget that the bearings of the case are completely changed by the acquisition of Cyprus. It is no longer necessary, from a military point of view, to bring England and India into direct communication with each other—Cyprus being our representative now. It becomes simply a question of forming a triangle between Cyprus, Bayazid (on the Russo-Perso-Armenian frontier), and the Persian Gulf, so that from either end we can defend the Asia Minor frontier, as we are bound to do by the Anglo-Turkish Convention. This three-armed or Y-shaped line might follow the Cameron route from end to end, bifurcating at Mardin and passing through Diarbekr to Bayazid, which frontier town approaches it at right angles, a most important point in strategy. With reference to sending large bodies of troops by railway, a great deal of misapprehension exists as to the powers of a railway, both as regards its speed and capacity. The late Colonel Home, than whom there is no greater authority on military transport, showed that it would take longer to send an army corps to York from London by railway than it would for them to march, although there are several double lines in the example he quotes, and only a single line in this case. Single line railways as a military means of transport are, therefore, of little use, and are not fitted to carry any large number of troops, for to box men up in the way Colonel Champain described would, of course, be quite impracticable, except on an emergency. Referring for illustration to the Afghan campaign, it will be found that the enormous number of camels and mules employed transported stores for the troops, but not the men themselves, and the value of this line would be confined to doing similar duty—at far less expense—and with permanent advantage, creating means of transport instead of destroying them. Even for Cyprus, where is the grain to come from to feed that country but from Syria? It is a great mistake for the advocates of this line to talk of the profit to be made out of through traffic. Excepting for the mails the extra transphipments alone would be fatal if the bare fact did not suffice that no goods can afford more than 400 miles of railway transport, except the line in question enjoys a monopoly of route, which is not the case here. Should the Canal be blocked, then having this last point of transhipment, on the eastern side of the Canal, so much nearer to India as the Persian Gulf is than Suez, enables the few ships available on emergency in Eastern waters to do as much carrying work as the larger margin of supply the Mediterranean always affords. From a "transport" point of view speed is of no value—regularity is what is wanted. Speed only affects the first delivery, and regularity is necessarily jeopardized by hurry. A single line like this would not carry through goods at a

greater speed than one mile an hour, counting the full time they occupied the company's premises. In France the legal rate of transit for heavy goods works out but a little over half a mile an hour, and at a corresponding diminution in tariff even a slower rate is accepted. Speed and cheapness cannot co-exist on a railway; they *may* do so on the sea where there are no differences of level to be overcome. Having agreed that the Indo-European line is necessary, the next point is the labor question. Can you get men? I say most emphatically no! From an economical as well as a philanthropical point of view, a great many people hold that making railways by hand is a first-rate occupation for the peasantry. It has even been proposed to adopt these tenets in Ireland, the population of which is 169 to the square mile; but first-rate politicians have agreed that it is suicide in that country to take a man away from his plough. Now, we have the same question in Syria, but under less hopeful circumstances; for there the population is only 32 to the square mile, not enough to cultivate the soil at the best of times, while there are thousands of acres only wanting men to cultivate them to produce many hundred fold for themselves and for the State whose revenue is essentially derived from the soil. Mr. Consul Skene is of opinion such works would grievously affect the revenue. What worst investment can be imagined that employing in such a case manual labor in cutting off the tops of mountains and filling up the valleys? If you make up your minds to construct a railway in such districts, you must either use mechanical means for constructing earthworks, and even then none of the works will be completed simultaneously, or you must do away with them altogether, and the latter I have shown to be quite possible. One notable fact with reference to the construction of military railways, necessarily made by hand, is this: that a railway made by hand has four times as much stuff in it as a railway made with the usual English plant, viz., of rails, wagons and engines, &c. If you buy two chairs or tables, one made by hand and the other turned out by machinery, no doubt there would be the same amount of wood in both; but in railway construction it is not so, for in making a railway by machinery the wagons transport the earth from the cuttings to the banks, and it is therefore the custom in our profession only to pay for one, as the two birds are killed with one stone. But when you make a railway by hand, you cannot transport the stuff even a few yards, and every load of earth taken from the cutting must be thrown away and wasted, while every load of earth required for the banks has to be sought for afresh, and scraped together, perhaps, from a considerable superficial area. Owing, moreover, to the want of mining tools to blast the rocks with, cuttings are reduced to a minimum, and the banks correspondingly heightened, *i. e.*, practically doubled in depth. Now, since a 20-foot bank has four times as much in it as a 10-foot bank, it results that a railway made by hand will require about four times as much labor as if made by machinery; and, in addition, if in England, where coal, iron, and mechanical talent are drugs, £50,000,000 of railway capital pays no dividend, such works can hardly be expected to flourish in Mesopotamia.

Lieutenant-General Sir JOHN ADYE, R. A., K. C. B.—I am desirous of making a few remarks upon the lecture we have just heard by Commander Cameron, and am sorry to say he has not convinced me thát either in a commercial or in a military point of view, it would be desirable that we should assist in making a railway through Asiatic Turkey as a means of communication with our Empire in India. As regards the commercial aspect of the question, our goods are now transported in vast quantities from the ports of England with ease and facility by sea through the Suez Canal, and within a month are landed in Bombay without transphipment, but if we adopted this proposed line, we should have to land our goods on the coast of Syria, where there are no good harbors, and where the country is unhealthy, and after a long journey by land should have again to embark them at the Persian Gulf, a country equally unhealthy, and devoid of good harbors and facilities. Would that, in a commercial point of view, be a desirable arrangement? Let me read a short extract from a letter that appeared in the *Times*, on the 11th

of December, 1879, signed W. H. I. The writer said:

"As a commercial enterprise the formation of such a line would, I venture to say, be a dead failure and prove sadly disappointing to any persons who had been foolish enough to embark capital in the undertaking in hopes of a return. That, after a steamer has been loaded and dispatched from London, Liverpool, or Glasgow, the whole of the cargo should be turned out at Beyrout or some other Syrian port, there loaded in railway trucks for conveyance through Mesopotamia, discharged out of those trucks at a port on the Persian Gulf, and a second time loaded on board a steamship for India, instead of being allowed to proceed to India direct in the original vessel which had sailed away from England, is an idea so preposterous in the eyes of all men of business that it may almost be dismissed without comment. Have your correspondents ever calculated, or attempted to calculate, the enormous expense which would be created by this extra handling of goods (to say nothing of the loss that would be caused by breakage or exposure), and compared this expense with the trifling gain which might possibly be derived from the shortening of the transit by five or six days?"

In a military point of view, I think there are great objections to the proposed route. In the first place, our troops are now transported with ease and comfort by sea in four weeks to Bombay, and it appears to me that that is the safest and most prudent course, which we, as a great naval Power, could adopt. But if taken in the way proposed, we should have to land our troops on the coast of Syria, and, after a long fatiguing journey of many hundred miles, should have again to embark them where there are no facilities, in a very unhealthy corner of the Persian Gulf. But there are greater military objections than that. This line of railway, if completed, would not belong to England, but would traverse the territory of another Power—that is, Turkey. Surely, it is not desirable that we should be dependent on another country for the line of our military communications with our Indian Empire. Another still greater objection is, that this line of railway would be open to danger at all points, while the Suez Canal is practically free from attack by land. By adopting such a proposal as that now under consideration, we should therefore not only be dependent on Turkey, but our line of military communications would run across the front of, and be in comparative proximity to, the armies of another great Power—that is, of Russia on the Armenian highlands. Surely, such an arrangement would not commend itself to the judgment of military men. In my opinion, therefore, the route would commercially be a failure, and in a military sense it would not only be useless, it would be a danger.

Capt. J. C. Colomb, R.M.A.—The last speaker has anticipated what I wished to say. The general question is that which has first to be considered. We have drifted into a good many mistakes in our time; we all know that, we have only got to consider what our Empire is at this moment to know it. We have a telegraph cable the wrong side of Africa, and we have our communications between two extremes of one of our great Colonies passing through a foreign country; therefore, I think of all things in considering a great question like this, we should really be careful to clearly understand whether, in its broadest sense, the proposed line is or is not desirable from an Imperial strategic point of view. And I must say, having looked into these questions, I entirely concur with Colonel Champain and the last speaker. I will not take up the time of the meeting by giving reasons which have already been given, but I should like to ask Commander Cameron if he would be kind enough to answer one question. In making a railway what we have to consider here is its strategical or military aspect purely, because commercially we have nothing to do with it, for this reason: that if it is a commercial speculation worth anything, we may depend upon it commercial men will take it up. In this Institution, I take it, we must only look at it from Imperial strategical ground. I confine myself very briefly, therefore, to this one remark. Commander Cameron spoke in rather an offhanded way, I think, considering our military resources as regards men, and when he said that if the Suez Canal was blocked, of course troops from

India and troops from England would meet at points in that proposed railway. I should ask him to consider, Have you got the troops? Are you going to make a great English line for strategical reasons without making preparations for its adequate defence? That is a very serious point. He said if the passage through the Suez Canal was stopped, we could carry on our traffic by that railway; but that, I consider, entirely depends in what way the Suez Canal is stopped. Is he contemplating the cutting of the sea communication by Alexandria, or between Alexandria and England, because if so, what becomes of your sea communication with the Mediterranean terminus of this proposed line? It appears to me that you would divide your power of defending your line of sea communication. We should never permit the stoppage of our communications through the Suez Canal; and to make your railway because you are content to think we may lose that route, is to my mind a mistaken policy. I simply ask Commander Cameron to explain how that land line of communication would enable us to recover our control of the Suez Canal when the control of the Suez Canal is really a naval question.

Mr. C. E. Austin, C. E.: I wish simply to say a few words on the commercial view of this question, for I know very little about the strategical part. With regard to the heat in railway carriages in these climes, I have had some experience in Brazil, and I did not find it so extremely oppressive as Colonel Champain thinks it would be. In Brazil we travel very easily. In Smyrna, again, where the heat at some times of the year is very oppressive, we travel very well in railway carriages, and we find no difficulty in so constructing our carriages as to keep the people cool inside. During the Russo-Turkish War we carried many thousand soldiers on the Smyrna and Cassaba Railway. With regard to the bugbear which drives all our commercial men away from railway speculations in Asiatic Turkey, so that without the aid of Government, and a guarantee on the money expended in the construction of these lines, they never will embark in them, it is the idea that you cannot work with the men of the country. The Kurds are tabooed; the Circassians are said to be people nobody can control. Midhat Pasha has been constructing roads in Asia Minor; and last April I had the pleasure of laying out the commencement of the Tripoli line, three miles in length, from the port of Tripoli to the town. I accompanied Midhat Pasha from Beyrout to Tripoli, whither he went more especially, because they told him 40,000 Circassians were collected at Tripoli, and there was much fear that they would become unmanageable. He went there and found 5,000 Circassians and Tartars, whom he set to work to make a road from Tripoli to Homs. We tried the Arabs, (the people of the country), and compared them with the Circassians; but the Circassians did much more work than any Arab, and they were taught with the greatest ease. They are the people on whom Midhat Pasha depends for making his carriages, and working the carriages on his roads. In every country that they go to, the Crim Tartars and Circassians introduce the carriage which does not exist in those countries. With regard to the Kurds, we have employed on the Smyrna and Cassaba Railway bands of Kurds; they are admirable laborers; they are much more easily taught than Greeks and Turks. The Turks are very good laborers too; but all the men we are the most afraid of, when they are turned to work, prove to be the best workmen we have. The best zaptiehs all over Syria are Kurds; the best country proprietors are Kurds; wherever you meet a Kurd you like him. I had a zaptieh with me, a sergeant, who traveled with me a long while. That man was a well-disciplined soldier; and although I was an Englishman and a Christian, and he a Mahommedan, he would come and pull off my boots in the evening, and would do any menial service for me, which an Arab would not willingly have done. He considered me as a friend of his master, and did not think of my religion in any way. With these facts in view, we must naturally infer that the Bedawee who inhabit the nomad districts of Syria and Mesopotamia, through which the proposed railway must pass, and who are only nominally Mahommedans, and much more liberal in their tenets than Mussulmans, would rather aid than hinder the construction and maintenance of the line. Then, as to commercial profits, I must say, Com-

mander Cameron's line, comparing it with the Euphrates Valley Railway from Alexandretta is a possible line, whilst the other is an impossible line. The gradients on his line are moderate, and there are no gradients against the traffic; whilst on the Alexandretta line it is stated that there are gradients of 1 in 13. The country being an agricultural country, the heavy traffic will consist in exports; and, in making a line of that sort, we must have no gradients against the traffic to the shore. The quantity of our import goods will be small in comparison, but it will be more valuable and pay more for carriage. The line proposed by Captain Cameron leaves out of the scheme a very large town, namely, Damascus. The traffic between Damascus and Baghdad is very large. Thinking, as I do, that there is not the slightest difficulty in setting these tribes to work, whether nomad, Arabs, Kurds, or Turks, I cannot see why you should not save 280 miles of railway, and go straight from Homs to Baghdad. Baghdad is the great emporium of the East, and the great object is to make the most direct communication with the west from that great emporium and the Persian frontier. By doing so you bring the traffic to Homs, which, in ancient times, was a very large town, and a very great center of commerce. From Homs the goods brought from the East can be dispatched over good roads either to Damascus or Aleppo, and the straight railway is sure of the traffic from Baghdad to both these towns as far as Homs. There is no difficulty in running across the steppes of Mesopotamia. They are as flat as a table, so that the line will cost comparatively little, and the traffic expenses be very light. However, into the details of construction this is not the moment to enter.

Mr. Trelawney Saunders: As you are quite aware, the naval power of this country can be exercised up to the shores of Syria on one side, and up to the head of the Persian Gulf on the other; and the simple question is whether it is desirable to complete the missing link, and connect those two points by a railway. In this Institute you may dismiss questions of commerce. If that missing link is to be supplied, you will probably conclude that it should be by the shortest and safest route. The author of the present paper has endeavoured to argue in favor of the Tigris as against the Euphrates, which unquestionably marks the shortest route. He has endeavored to persuade you that the Tigris is preferable, because it has more large towns upon it. But we must all recollect that we are not dealing in the present case with simply the supply of railway communication to certain towns in the Turkish dominions, but with the question—how this country and India can be most easily connected. It is admitted that we already have a line of communication *viâ* the Suez Canal. Very good; but is it desirable that we should depend under all circumstances upon one line of communication only, for you may almost put the line by the Cape of Good Hope out of the question? Most people agree that it is not desirable to confine communications of a great Empire to one line, and it is contended that the line of communication by the Persian Gulf and the Mediterranean should be made as an alternative to Suez. With regard to the present distribution of the population in the Tigris and Euphrates Valley, it must be in the remembrance of every one who has studied this subject that the time was when the Euphrates also had considerable towns at very short intervals along its banks; and there can be no question that with the establishment of a railway and the restoration of good government in Asiatic Turkey, the towns on the Euphrates would revive again. In fact, wherever you carry such a line of railway, population will follow it. It must be presumed that great facilities are offered by the Euphrates line, to account for the persistence with which its claims have been advocated for the last twenty years by Mr. W. P. Andrew. There must be good ground why a man of his railway experience and good judgment should so persistently adhere to that opinion. The Euphrates is not only the shortest line, but by keeping to the south bank, there are no affluents to cross, and having no rivers to cross, there are no bridges to make, nothing but a plain to traverse. There is also another advantage, to which I may point, inasmuch as it has been alluded to by a previous speaker of great eminence, I mean the advantage of having interposed between your railway and any enemy advancing from the north, two great rivers, which

would certainly be a great protection to the line south of the Euphrates. But there is a condition preceding that that has to be borne in mind in forming any opinion upon this question, and that is the following; No great public work could be undertaken in Asiatic Turkey in the present disturbed state of its administration. Therefore, it is to the establishment of good government in those countries that every one who is interested in opening up and improving communication through them with India should direct his mind at this moment. Everything should be done, I contend, to support any Government (I care not what party may be in power) in introducing into these regions, that were formerly the finest and fairest and best of the earth, that have still the natural fertility and productiveness and the industrious populations that would make them again the seat of wealth, and that need nothing but good government to restore the prosperity that made them formerly the seats of great Empires—on that point, the restoration of good government to those countries, already the opinion of the Powers of Western Europe has been brought to bear with great unanimity, and we should allow no differences of faction, no differences springing merely from political partisanship, to put difficulties in the way of that great object.

Mr. Trelawny Saunders—I am arguing that we should all unite in promoting good government in Asiatic Turkey, and following upon good government, you may rely upon it, all questions of railway communication will very soon settle themselves. Whether you have a line by way of the Euphrates or Tigris, sooner or later that line will form a part of a general system of communication, which will connect Constantinople and Smyrna, as well as the ports on the Mediterranean, with Mesopotamia, the Persian Gulf, Persia and India. A certain boundary has been fixed on the frontier of Armenia, which we are engaged to maintain. Another boundary has been fixed upon the River Oxus, which we have defined, and are concerned in maintaining. Why are those boundaries fixed? They are fixed as barriers, beyond which a certain Power must not advance southward. But there is an interval between those two fixed barriers that remains unprovided for, namely, Persia. Is it intended that in that interval or through it any hostile Power may advance to the Persian Gulf, or to the mouth of the Euphrates, or to any other point between India and the Mediterranean that will suit its purpose? I think not, and therefore it must be clear and obvious, that whatever policy is directed towards the Armenian barrier at one end and the Oxus barrier at the other, must also be directed to the Persian link that lies between those two barriers. That is a matter necessary to be borne in mind, and to be brought into action, before you can connect India through Persia with the line of the Euphrates Valley. I am glad to find my friend Mr. Andrew adhering to the Euphrates Valley line, and if that line is to be extended to India, the ground must be made sure in the interval that lies through Persia.

Commander Cameron, in reply, said—Colonel Champain talks about the local traffic. I never would expect any railway to be paid for by its through traffic, but I believe the construction of the railway will attract people there who will settle on the ground and cultivate it, and will give us such an enormous traffic as will give a very good return on the railway. At present there are 400 tons, without the Aleppo trade, which comes from the line by Homs and Hamah every day, and goes coastwards. A short way further back, wheat can be bought for five to six shillings a quarter, and it is delivered on board ship at over forty shillings. I utterly put on one side any idea that any traffic by the Suez Canal is to be diverted on to our own line; it is to assist the Suez Canal, and I believe the opening of that railway will cause increased traffic through the Suez Canal. As to Bushire having no harbor, and ships of any draught having to unload three miles out, there is a little bar which might be dredged, and then there would be thirty feet of water close up to the town. We cannot make harbors without spending money, and if we are to have a great scheme like this, we must pay for making harbors. There is a very good opportunity for making a good harbor at Bushire, and also a magnificent harbor at Tripoli. I agree with Mr. Scott Russell about the railway going from

Constantinople. I do not think for our mails it is good to cross too many frontiers, but if the shortest route is by those frontiers, *perhaps*, it may prove best to cross them. If we cannot carry out the whole of this international scheme, why should we not make that section which is most important to us nationally, and let the other follow hereafter? Mr. Haddan talks about mechanical works in a railway, I suppose if we go out there, we shall employ the latest developments of mechanical science. The population are doing nothing for many months in the year, and a great portion of them are stowed together miserably in the towns, on account of taxation, who would, by the fact of this railway being constructed, be first drawn out in the open country to be constructors of the railway, and afterwards become cultivators of the ground. As for the troops, of course, the right way for our troops to go to India for all ordinary purposes is by the Canal; but if this line goes to Mosul, and I hope it is going to Persia some day, we may some day have war there, and then, by giving us the opportunity of bringing stores to such advanced points as Mosul and Diarbekr, the principal point in the defence of Kurdistan and Armenia, this railway will be of value to us. Then there is another thing. I never contemplate losing the command of the Mediterranean. I do not believe that England will ever lose the command of the Mediterranean or any other portion of the sea, but we know that dynamite and gun cotton are easily conveyed to the most extraordinary places, and in ten minutes' time anybody going through the Suez Canal might block it so that it could not be open for six months. It might happen that, at that particular time, all our ships might be on this side, and then, although we might take troops across the isthmus by railway, we should not have ships to carry them on. But if we could take them up to Bushire, we might in the meantime, telegraph to India to send ships. In answer to Captain Colomb, it is a great thing to be able to convey small bodies of troops rapidly, and thereby make them equal to large bodies of troops, that cannot be conveyed so rapidly. As to Kurds and Arabs, I may be prejudiced in favor of the Arabs. As for a Kurdish servant pulling off one's boots, I have gone into an Arab Shiek's tent, and he has pulled off my muddy riding boots himself, and you do not find hospitality like that in every place.

Mr. Austin—I meant to say these were the people tabooed; the Arabs most likely would be better than they.

Commander Cameron—Mr. Saunders still goes with Mr. Andrew. Now, I admire Mr. Andrew most thoroughly, but, at the same time, I must differ from him entirely. Iskanderoon is not a harbor, and a summit level of 2,200 feet has to be ascended in seven miles. A great portion of the Euphrates Valley is barren, and the population cannot live, while history tells us that, when the Emperors Julian and Cyrus the younger descended the Euphrates for a large part of the march, they were dependent on their flotillas for supplies. As for having two rivers instead of one to defend us, I should be very much ashamed if we wanted two instead of one; I should be very glad to use the Tigris by going down the right bank, but to go and put 200 or 300 miles and another river between us and a possible enemy, and leave a good position, I should be ashamed to run out of the way like that. Colonel Chesney quoted here, in July, 1857, "Europe is no longer the world. The key to "the possession of the world is the Valley of the Tigris, and not Constantinople." I hope that this railway will come to pass, and give us the command of that Valley of the Tigris."

Improved Voltaic Batteries.—Some time ago M. Azapis suggested using a solution of chloride of sodium or of sal ammoniac for the acidulated water in contact with the zinc of a Bunsen battery, and the success of the change has led Mr. David Lindo, of Falmouth, Jamaica, to substitute sulphate of sodium for the dilute sulphuric acid in contact with the zinc of a Grove battery. Chlorine compounds might prove injurious in the Grove, and were therefore neglected for the sulphate of sodium. The substitution has given good results; no amalgamation of the zinc is required, and the intensity of the current is as great as where dilute sulphuric acid is employed. Moreover, the solution of sulphate of sodium answers well in the Bunsen cell.

THE FLUID DENSITY OF METAL.

ON THE FLUID DENSITY OF CERTAIN METALS.*

By Prof. W. CHANDLER ROBERTS, F.R.S., and T. WRIGHTSON.

THE authors described their experiments on the fluid density of metals, made in continuation of those submitted to Section B at the Swansea meeting of the Association. Some time since one of the authors gave an account of the results of experiments made to determine the density of metallic silver, and of certain alloys of silver and copper when in a molten state. The method adopted was that devised by Mr. R. Mallet, and the details were as follows: A conical vessel of best thin Lowmoor plate (1 millimeter thick), about 16 centimeters in height, and having an internal volume of about 540 cubic centimeters, was weighed, first empty, and subsequently when filled with distilled water at a known temperature. The necessary data were thus afforded for accurately determining its capacity at the temperature of the air. Molten silver was then poured into it, the temperature at the time of pouring being ascertained by the calorimetric method. The precautions, as regards filling, pointed out by Mr. Mallet, were adopted; and as soon as the metal was quite cold, the cone with its contents was again weighed. Experiments were also made on the density of fluid bismuth; and two distinctive determinations gave the following results:

$$\left.\begin{matrix}10.005\\10.072\end{matrix}\right\}\text{mean, } 10.039.$$

The invention of the oncosimeter, which was described by one of the authors in the Journal of the Iron and Steel Institute (No. II., 1879, p. 418),† appeared to afford an opportunity for resuming the investigation on a new basis, more especially as the delicacy of the instrument had already been proved by experiments on a considerable scale for determining the density of fluid cast iron. The following is the principle on which this instrument acts:

If a spherical ball of any metal be plunged below the surface of a molten bath of the same or another metal, the cold ball will displace its own volume of molten metal. If the densities of the cold and molten metal be the same, there will be equilibrium, and no floating or sinking effect will be exhibited. If the density of the cold be greater than that of the molten metal, there will be a sinking effect, and if less a floating effect when first immersed. As the temperature of the submerged ball rises, the volume of the displaced liquid will increase or decrease according as the ball expands or contracts. In order to register these changes the ball is hung on a spiral spring, and the slightest change in buoyancy causes an elongation or contraction of this spring which can be read off on a scale of ounces, and is recorded by a pencil on a revolving drum. A diagram is thus traced out, the ordinates of which represent increments of volume, or, in other words, of weight of fluid displaced —the zero line, or line corresponding to a ball in a liquid of equal density, being previously traced out by revolving the drum without attaching the ball of metal itself to the spring, but with all other auxiliary attachments. By means of a simple adjustment the ball is kept constantly depressed to the same extent below the surface of the liquid; and the ordinate of this pencil line, measuring from the line of equilibrium, thus gives an exact measure of the floating or sinking effect at every stage of temperature, from the cold solid to the state when the ball begins to melt.

If the weight and specific gravity of the ball be taken when cold, there are obtained, with the ordinate on the diagram at the moment of immersion, sufficient data for determining the density of the fluid metal; for

$$\frac{W}{W'}=\frac{D}{W'},$$

the volumes being equal. And remembering that W (weight of liquid) = W′ (weight of ball) + x (where x is always measured a $+ve$ or $-ve$ floating effect), there is obtained the equation:

* Abstract of paper read before Section C (Chemical Science), British Association meeting, York.
† See also *Engineering*, vol. xxviii., p. 329,

$$D=\frac{D'\times(W'+x)}{W'}.$$

The results obtained with metallic silver are perhaps the most interesting, mainly from the fact that the metal melts at a high temperature, which was determined with great care by the illustrious physicist and metallurgist the late Henri St. Claire Deville, whose very latest experiments led him to fix the melting point at 940° Cent. The authors of the paper showed that the density of the fluid metal was 9.51 as compared with 10.57, the density of the solid metal. Taking their results generally, it is found that the change of volume of the following metals in passing from the solid to the liquid state may be thus stated:

Metal.	Specific gravity, solid.	Specific gravity, liquid.	Percentage of change.		
			Decrease of		
Bismuth	9.82	10.055		volume	2.3
Copper.	8.8	8.217	Increase	"	7.1
Lead...	11.4	10.37	"	"	9.93
Tin....	7.5	7.025	"	"	6.76
Zinc....	7.2	6.48	"	"	11.10
Silver..	10.57	9.51	"	"	11.20
Iron....	6.95	6.88	"	"	1.02

PERMANENT WAY CONSTRUCTION.

From "Glaser's Annalen fur Gewerbe und Bauwesen" for Abstracts of Institution of Civil Engineers.

The author points out that if railway extension continues to proceed at the same rate it has been doing in this century, by the end of the next two centuries the combined products of all the forests in the world will be insufficient to supply the number of wooden sleepers required in railway construction; and that therefore any truly comprehensive solution of the question must provide a substitute that will comply with all the requirements it is possible to anticipate. Iron would not only satisfy these, but also afford profitable employment to the daily increasing industrial population of the principal countries of the world. The superiority in every respect of iron over wooden sleepers is not, however, universally admitted; to prove it, three questions must be satisfactorily answered, namely, those of cost, simplicity and safety.

As regards wooden sleepers, in the first place the best kinds of timber for sleepers are now not procurable in any appreciable quantity. The first cost and maintenance charges for wooden sleepers do not by any means show so marked a superiority over those for iron sleepers. According to Hilf's comparison between his system of longitudinal iron sleepers and wooden transverse sleepers, calculating fifty-six years as the life of the former, there is a yearly balance of 460 marks per kilometer (about £35 per mile) of line in favor of the iron sleepers, without calculating the value of the old material. The correctness of this estimate has, as far as is known, never been disputed. As regards simplicity of construction, no objection can be urged against wooden sleepers; as regards maintenance, there are many serious ones, involving safety to traffic, careful inspection, and labor in repairs.

Safety is endangered by the difficulty of keeping the line to gauge, owing to the imperfect hold the sleepers exert on the spikes, which is due to the variable holding properties of timber under different conditions, and the gradual destruction of the fiber from the blows transmitted through the foot of the rail during the passage of trains. A want of uniform rigidity of the road, due to the different ages of the sleepers produces conditions which seriously injure the rolling stock. The use of wooden sleepers does not recommend itself on the ground of cost and safety to traffic. Next the question of iron transverse sleepers demands attention; the advantages claimed for them are simplicity in construction and renewals, rigid maintenance of gauge, simplicity of drainage, durability, and handiness in time of war. The first cost, and cost of laying of both transverse and longitudinal iron sleepers is about the same. As regards maintenance, sufficient data are not procurable for a correct comparison, but it is presumable that with good ballast the

more equal distribution of the load on a longitudinal sleeper road would reduce the cost of maintenance.

Simplicity of construction is claimed for the transverse sleepers, on the grounds of greater handiness of the parts; but, then, again, the fact that one longitudinal is equal to four transverse sleepers should not be lost sight of. In laying curves, the longitudinal system certainly requires greater care and precision, and the work of renewing is more complicated; in time of war this is an acknowledged defect. A superiority in respect of maintenance of gauge is claimed for the transverse, but it is no less obtainable in the longitudinal system as exemplified in the Berlin municipal, Hilf, and Rhenish railway permanent way.

A decided objection to iron transverse sleepers is, that they do not afford the same hold on the ballast the heavier wooden ones do; that they require to be bent in order to give the proper cant to the rails, and in consequence are always liable to revert to their normal condition. Again, the fracture of a rail on a cross-sleeper system is attended with far more serious consequences than could possibly occur with the longitudinal system.

Longitudinal sleepers were the first made use of; transverse were not introduced until 1876. Even in the earliest times the following requirements were recognized as requisite for a perfect system of superstructure: (1) a head of a section sufficient to resist the wear; (2) a web deep enough to carry the weight; (3) a base sufficiently broad to distribute the load on the ballast. These conditions are perfectly realized by the longitudinal system alone, the best examples of which are furnished by Hilf, Haarmann, and the Rhenish railway.

The author then proceeds to discuss the relative advantages and disadvantages of the Hilf, Haarmann and Rhenish railway permanent way, to enumerate the evident objections to every system of transverse sleepers, and to combat and answer all objections to longitudinal sleepers, referring to the absolute necessity of greater attention being paid to the conditions of safety of a line, in consequence of the growing desire for an increased rate of speed, which likewise demands heavier engines, and these again introduce further elements of danger to the permanent way, straining it more severely and rendering cases of derailment more frequent and more serious.

A serious accident which occurred on the Cologne-Minden railway shortly after the speed on that line had been experimentally increased, drew attention to the subject and led to a series of experiments, as to the resistance offered by the various types of permanent way to the forces exerted by the rocking of a heavy engine. This also appeared a good opportunity for testing the relative efficiency of the various descriptions of permanent way. But the results of these experiments, however interesting, were not of a character to afford any practical solution of the question, as the actual conditions of the case were not correctly reproduced. Accordingly another plan was adopted, viz., an ordinary railway wagon (tare 4,500 kilogrammes), loaded with 18,500 kilogrammes of iron, was provided with a gallows, from which was suspended by a chain, 5 meters in length, a block of cast iron weighing 228½ kilogrammes, at a distance of 1.75 meters (wheel base of the Cologne-Minden locomotives) from the loaded axle. This weight, with a swing of 3 meters (equal to a vertical fall of one meter), was made to strike the inner side of the rail, the results of which are given in the four tables appended to the paper, and were registered by means of a lump of clay resting against the outer edge of the rail.

The apparatus and weights made use of in these experiments more than satisfy the conditions it was sought to reproduce, and afford a reliable test of the capacity of the various systems to resist the effects of the rocking of a heavy locomotive; the results are unfavorable to the system of transverse sleepers, but prove that a well-constructed permanent way with longitudinal sleepers is capable of providing perfect security in this respect.

The author's own comments on the behavior of the different types experimented on, and his deductions therefrom, are given in full, and conclude with a remark that though the behavior of permanent way in presence of such horizontal forces is certainly not alone conclusive

as to the value of any one system, since many other questions must necessarily also enter into the determination, yet the results of these experiments go a long way towards a solution of the question in favor of the use of longitudinal sleepers.

REPORTS OF ENGINEERING SOCIETIES.

American Institute of Mining Engineers.—The Autumn Meeting begins with the 25th of October, the programme is at this date, Oct. 17th, not at hand. The transactions of the last meeting are in process of distribution. In the last supply received from Mr. Thomas M. Drown, the Secretary, we notice :

"Investigations of the Ore Knob Copper Process," by T. Egleston, Ph.D.

"Notes on Gold-Mill Construction," by Augustus J. Bowie, Jr.

"Manganese Determinations in Steel," by Wm. Kent, M.E.

"Note on Black Band Iron Ore in West Virginia," by S. P. Sharples, S.B.

An important paper published in advance of the October meeting is :

"Chemical Methods for Analyzing Rail Steel," by Magnus Troilus, Chemist to C. P. Sandberg.

The Boston Society of Civil Engineers.—The last published paper is that of the June meeting :

"Sheeting and Bracing Sewer Trenches," by Mr. William Whittaker.

Polytechnic Association of the American Institute.—The principal topic of the session of Oct. 1st was :

"The Various Systems of Raising Water," presented by the President, Mr. Thomas D. Stetson.

Oct 8th—The subject of "Ozone" was presented by Mr. P. Rudisch.

ENGINEERING NOTES.

St. Gothard Tunnel.—"I drove down alongside the St. Gothard Railway from the western end of the tunnel to Lake Lucerne, where the lines join those leading to Germany. What you will be most interested to know—how they are getting on with the slip in the mountain—I did not have a chance to ascertain, but I can give you some of the usual kind of travelers' information out of the guide book. The grade to and from the tunnel averages about 1 in 40. The tunnel, already open, and being lined, is 9¼ miles long, and is 1⅝ miles longer and 600 feet lower than the Mt. Cenis tunnel.

"The interesting features which I saw were the stupendous works for getting up the rapidly rising gorge at Wasen. At this point, in a chasm between precipitous mountains, by means of five bridges and a tunnel, the road makes a double loup, and then by two tunnels it makes two complete circles in the mountain; in these tunnels the road crosses itself.

"The character of the work is most thorough. I never examined better railway masonry and drainage structures. I especially noticed the size of the stones (range work) and the mass of the various abutments and buttresses, thus adding the stability of weight to that of accurate workmanship. The rough torrent beds where freshets and avalanches come down, were replaced by round bottomed, inclined masonry chutes, often 100 feet or more wide, and running 1,000 feet up the mountain side. The iron bridges have rather short spans, and riveted connections invariably. The line is single, and the works do not look wide enough to add another line. I think that the average American capitalist would not like to be a shareholder in this railroad."—A. L. Holley to *American Machinist.*

The Mersey Tunnel.—The operations in connection with the tunnel which the Mersey Railway Company are boring under the Mersey from Liverpool to Birkenhead are being rapidly pushed forward. On the Birkenhead side the permanent pumps are now in position; and continuous work day and night, with three shifts of workmen, has gone forward with the test or drainage heading. The length cut last week was eleven yards. This is all done by hand, with the aid of explosive gelatine, the confined space making the application of boring machines difficult. This heading is now well under the river, and no increase of water is perceptible. In fact the water does not now present any feature of difficulty, and engines keep it under even when working dead slow. The company's engineer and the contractor have now decided that the main tunnel shall go forward at the same time as the drainage heading, and permission has been obtained from the Mersey Dock Board to sink a second shaft close to the existing one in order to expedite this work, and this has already been carried down a considerable distance. On the Liverpool side less rapid progress has been made, owing to the fact that the upper part of the shaft had to be sunk through made ground, and also on account of the confined space on the quay within which the work has had to be carried on. The permanent pumps, however, are now fixed and at work, and they are found to exhaust the water with the engines working at the same slow rate as on the other side. As soon as a sump for the permanent drainage has been completed at the bottom of the shaft, which will be in about a week hence, the heading, which is already about a hundred yards in length, will be proceeded with. It is in contemplation to apply for permision to sink a second shaft on the Liverpool side, and this will shorten the time for the completion of the railway by a period of nearly six months.

RAILWAY NOTES.

Railways of the United Kingdom in 1880.—Although the "Railway Returns" for 1880 have not yet been issued by the Board of Trade, some of the main features of the movement, as ascertained from the "Sta-

tistical Abstract for the United Kingdom from 1866 to 1880," has been given in the *Builder*. In the following figures the returns for 1879 can be compared with those of 1880 :

Length of railways open in the United Kingdom :	
1879	17,696 miles.
1880	17,945 "
Total capital paid up in shares and loans :	
1879	£717,003,469
1880	728 621,658
Number of passengers conveyed (exclusive of season-ticket holders):	
1879	562,732,890
1880	603,884,752
Number of passengers per mile:	
1879	31,800
1880	33,652
Total traffic receipts:	
1879	£59,395,282
1880	61,958,754
Traffic receipts per mile:	
1879	£3,356
1880	3,453
Working expenses:	
1879	£32,045,273
1880	33,502,349
Net Traffic receipts:	
1879	£29,731,430
1880	30,985,094

A WRINKLE IN PERMANENT WAY.—Not withstanding that many hundreds of so-called improvements in permanent way have been patented since railways became general, the old form of permanent way, consisting of a double-headed rail, cast-iron chair and wooden key, spiked or trenailed down to transverse timber sleepers, still obtains on the great majority of our lines. It is true that wrought-iron sleeper systems are at last being tried on some of them, but this is when our engineers find them largely coming into use on the Continent, particularly in Germany. We do not, however, propose a dissertation upon permanent way generally, our intention only being to place before our readers a very simple and practical improvement which has recently been effected in the ordinary permanent way of his line by the engineer of the Great Western Railway Company. This consists merely in reversing the chair and shifting the wood key from the outside to the inside of the rail. This re-arrangement gives several points of advantage, and in no way interferes with the working of the line, as the keys are clear of the flanges of the wheels of the vehicles. One of its chief advantages as regards the safety of trains is, that should a key work loose or even fall out, the gauge of the line will be rigidly maintained under passing trains. Should, however, such an occurrence take place with the keys on the outside, the gauge of the rails must necessarily be widened to some extent during the passing of a train, thereby constituting a source of danger. Then with regard to inspection, much time is saved to the plate-layer in his examinations, as he need only walk once down each pair of rails instead of twice. This sensible arrangement is, we recently observed, being adopted on the Great Northern Railway, and we doubt not engineers of other lines will follow the practice as opportunity offers.

RAILWAY RETURNS.—From the railway returns of England, Scotland, and Ireland for the year 1880, just issued, it appears that the total authorized capital up to the date of the return was £802,014,004. The total paid-up stock and share capital was £546,558,217, and the total raised by loans and debentures £181,758,631, making a gross total of £728,316,848. The length of line opened for traffic on December, 1880, was 17,933 miles. The total number of passengers conveyed, exclusive of season-ticket-holders, was 603,885,025 against 562,732,890 in 1879. The total of traffic receipts was £62,961, 797, showing a considerable advance on the £59,395,282 of 1879, and in fact being at the rate of £3,551 per mile instead of £3,356 in 1879, and £2,755 in 1866. The working expenses were £33,601,524, a million and a half increase during the year. The net receipts were £31,890,501, against £29,731,430 in 1879. The mean cost per mile over the whole system has risen from £40,518 in 1879 to £40,613 in 1880. The working expenses have fallen from 52 per cent. on the gross income in 1879 to 51 per cent. in 1880. The proportion of net receipts to paid-up capital is 4.38, against 4.15 in 1879.

CANADIAN RAILWAYS.—An important railway enterprise has been taken in hand at Montreal by Canadian and American capitalists. It is the building of a line, for which they have obtained a charter from the Dominion Government, from some point in the Canadian territory, on the Atlantic coast or Bay of Fundy, by way of Lake Megantic, Sherbrooke, Montreal, Ottawa, and French River, to a point on the east side of Lake Superior, receiving aid from Municipalities in Canada and the State of Maine. A meeting of shareholders was held August 30th to organise and commence surveys.

THE ST. GOTHARD RAILWAY.—The one-hundred and third report on the progress of the works of the St. Gothard Railway, reaching to the end of the first half of this year, has just been published. The principal and most difficult work, as we are aware, is the tunnel through the St. Gothard, of a length of 16,304 yards, or 9¼ miles. Its adit level has been driven this year, and more, the tunneling has proceeded for 13,215 yards, and been completed for traffic for 12,174 yards. No fewer than 3,319 workmen are employed in the tunnel, work proceeding uninterruptedly night and day. The contract value of the work done is £2,180,000, leaving still to be finished work to the value of £85,000. The quantity of compressed air used during the month of June for rock-boring machines and the locomotives employed in the carriage of materials and debris was 5,981,444 cubic feet per day. The temperature of the center of the tunnel was 29½° C. (85° Fah.), or 17° more than outside the tunnel. The quantity of dynamite used daily was 567 lbs. It may be remarked, in passing, that the temperature in the interior of the tunnel may possibly become lower, as has been the case in

the Mont Cenis tunnel, where it has fallen 7 or 8° C. during the last ten years.

Railway Accidents and Brakes.—At the usual monthly meeting of the Foremen Engineers and Draughtsmen Association, on September 3d, Mr. John Batey read a paper on "Continuous Brakes." He stated that it was of the highest importance for the safety of the public that an efficient brake should be used for the purpose of stopping a moving train and preventing disasters. It had been clearly shown that the recent railway accident at Blackburn would have been mitigated if the Westinghouse brake could have been properly applied, and therefore he considered that the subject was one which demanded public attention. The Board of Trade had drawn up certain conditions which they considered necessary to make up a good brake. Those conditions were based on the experiments carried out from time to time by Captain Galton and others, and nothing short of them, he urged, should be adopted by railway companies. He believed that the reason why railway directors did not carry out the request of the Board of Trade with regard to continuous brakes was because so many failures had been recorded in the Blue book. Although none of those failures were productive of serious results, still they had a tendency to weaken the faith of the strongest believer in their efficacy, and that was doubtless a clue to the want of unanimity of opinion amongst directors as to the best brake for universal adoption. He contendep that a brake to be efficient should have a power equal to the weight of the train, for the purpose of balancing the coefficent of friction between wheel and rail sufficient to hold the wheel, but beyond that it was necessary that a certain power should exist for the purpose of checking the ultimate velocity of the wheel. Therefore, the absolute power applied was represented by time, multiplied by the power applied. He disagreed with Captain Galton, who contended that the power applied, just short of that which was necessary to stop the rotation of the wheels, was a better means of stopping the train than skidding, which Mr. Batey considered opposed to theory and practice. He believed it was utterly impossible to bring an unskidded train, traveling at the same rate, to a standstill in the same time and at the same distance as a skidded one. That point appeared to have been finally settled by the trials on the Midland Railway, carried on by the authority of the Railway Commission, under Mr. E. Woods and Colonel Inglis; and he concluded that it was necessary that a brake should be applied equal in power to each vehicle in order to stop it, and thus avoid the unpleasant bumpings. A brake to be efficient, should be capable of being applied instantaneously. He then alluded to the proposals to stop a train by applying the power on the locomotive, which he thought insufficient for the purpose, and would cause the carriages to "telescope." With regard to Sanders and Bolitho's and Smith's vacuum brake, he deemed it open to three objections, viz., the ease with which the vacuum might be destroyed by the difficulty of retaining the same; the want and waste of motive power by the injector being kept going constantly; and the great difficulty of keeping up steam, owing to the injector blowing away in the smoke box and damping the fires. He next proceeded to consider brakes worked by compressed air, and stated that he considered the Westinghouse the best, but that, however, was open to many objections. According to the Board of Trade returns for the half-year ending December, 31, 1880, that brake had made no less than 307 failures. He concluded by alluding at some length to a brake which he had patented, the advantage of which he contended consisted in its exceeding simplicity. It was less liable to get out of order, in consequence of its small number of parts, and was also economical.

IRON AND STEEL NOTES.

The Bilbao Iron Mines.—By M. Baills.—The author gives descriptions and analyses of the three principal varieties of Bilbao ore—the campanil, vera dulce, and rubio, and remarks that the deposits probably consisted originally of homogeneous masses of carbonate of iron, interposed between beds of schistous grit below, and of limestone above, both of middle cretaceous age: and that the varying character of the ores now found appears to be due to the greater or less extent to which they have been weathered. Thus the deepest ore, now the vera dulce, is the least altered; that immediately under the limestone, the campanil, is more weathered; and that cropping out on the surface is the rubio, which contains the greatest proportions of water and of impurity. These typical varieties pass, insensibly, throughout the deposit, one into another.

The experience of wire rope tramways at the Bilbao mines has not been favorable; they are costly to maintain, and are liable to be interrupted by breakages of the rope, so that inclined planes, and ordinary railways, though more expensive, are on the whole preferred.

Some particulars are given at the end of the paper of the treatment of the softer ore (vera dulce) by the Chenot process, at the El Desierto works, near Barnacaldo. Each reducing furnace, used there for making spongy metallic iron from the ore, consists of two vertical brick retorts, 4 feet 7 inches by 1 foot in section, and 28 feet high. The retorts are heated externally by coal fires, and each of them is prolonged below by a sheet-iron cooler, 8 feet 1½ inch high. They are charged with ore and charcoal in alternate layers. The operation is carried on continuously, a portion of the reduced sponge being withdrawn at the bottom of the retort twice a day, and fresh ore and charcoal filled in at the top. The reduction of the ore and the cooling of the sponge require three days, and each retort thus yields about 0.72 ton of sponge every twenty-four hours, with a consumption of 1.27 ton of ore, 0.24 ton of charcoal, and 0.46 ton of coal. The cost per ton of the sponge is about equal to that of pig iron made at the same works. The sponge is made into balls of forgeable metal in

charcoal hearths, worked with blast at a pressure of 1.18 inch of mercury. Each hearth works in twelve hours, fifteen to twenty charges, consisting each of 202 lbs. of sponge and 55 lbs of charcoal. The cinder produced is very rich in iron; and 1 86 ton of sponge and 0.5 ton of charcoal are consumed per ton of bar made. The metal is very soft and malleable, and is specially used for nails for shoeing oxen.

The process seems likely, however, soon to be given up; it requires a very pure and a very rich ore, and the management of the operation is difficult. In working the sponge also into balls, the consumption of it is enormous. At the El Desierto works the number of furnaces in operation has been gradually reduced from six to two.—*Abstracts of Inst. of Civil Engineers.*

THE DEPHOSPHORIZATION OF IRON.—By Dr. K. List.—Dr. List's essay is an historical sketch of the attempts made to remove phosphorus from pig iron. He starts with the experiments of twenty years ago, and brings a very complete review of his subject down to the recent methods of Thomas, Gilchrist, and Snelus. He first notices briefly some of the wet processes which have been tried, with the object of freeing the ore from phosphorus, before smelting has been begun; treating them at considerable length the various processes, whether proposed, patented, or carried out, for removing the phosphorus during the process of reduction or after the metal has been reduced. The author has dealt with this extensive subject so concisely that an epitome of the paper would be little more than a list of names. It is not, therefore, attempted to abstract it, but simply to indicate its existence as a memoir which will be found of considerable value to any one requiring historical information upon the subject.

MAGNETIC IMPENETRABILITY OF IRON.—By J. Jamin.—The author recurs to the contested question as to the impossibility of causing magnetism to penetrate to considerable depths in iron and steel, and presents a series of experiments that he believes to offer a solution. There are placed, one above another, two equal bobbins wound with thick copper wire, separated by a third bobbin of fine wire which is connected to a reflecting galvanometer. A current in the two primary coils induces a current in the third and secondary coil. The arc shown by the galvanometer is recorded as a. There is then introduced into the three bobbins an iron tube ¼ of an inch thick. The primary current now induces a stronger secondary current, A; A—a measures the magnetization of the iron tube. Instead of the tube, a bar of iron equal in height is introduced, and the deflection A′ obtained. The bar is then placed in the interior of the tube, and a deflection A″ obtained. The following are one series of numbers:

A—a..............49.5
A′—a..............48.5
A″—a..............54.0

A″—a was then obtained with the tube and bar placed side by side=59.5.

The author considers these and other experiments he details to prove that the same current communicates to the bar much less magnetism when the bar is contained in the tube than when it is exterior to it, and that the tube takes greater magnetism in the first case than in the second. And he definitely asserts that ¼ inch concentric depth of iron completely arrests the magnetic effect of an external spiral.—*Abstract from Comptes Rendus for Inst. of Civil Engineers.*

THE EARLIEST CASTINGS IN IRON.—Cast iron is now in such general use that one might be apt to imagine that it had never been invented. But cast iron was not in commercial use before the year 1700, when Abraham Darby, an intelligent mechanic who had brought some Dutch workmen to establish a brass foundry at Bristol, conceived the idea that iron might be substituted for brass. This his workmen did not succeed in effecting, being probably too much prejudiced in favor of the metal with which they were best acquainted. A Welsh shepherd boy named John Thomas, had some little time previous to this been received by Abraham Darby into his workshop on the recommendation of a distant relative. While looking on during the experiments of the Dutch workmen, he said to Abraham Darby that he thought he saw where they had missed it. He begged to be allowed to try, so he and Abraham Darby remained alone in the workshop all night struggling with the refractory metal and imperfect moulds. The hours passed on and daylight appeared, but neither would leave his task, and just as the morning dawned they succeeded in casting an iron pot complete. The boy entered into an agreement with Abraham Darby to serve him and keep the secret. He was enticed by the offer of double wages to leave his master, but he continued faithful, and from 1709 to 1828 the family of Thomas were confidential and much valued agents to the descendants of Abraham Darby. For more than one hundred years after the night in which Thomas and his master succeeded in making an iron casting, in a mould of fine sand contained in frames and with air holes, the same process was practiced and kept secret at Coalbrookdale with plugged keyholes and barred doors.

ON THE RELATIVE POWER REQUIRED TO ROLL IRON AND STEEL.—By F. Braune.—In this paper some details are given of experiments made to determine the increase of motive power necessary to adapt a mill for rolling steel instead of iron.

The mill was a three high mill used for rolling deep joists, 60 feet long, and it was required to roll the same section and length in steel. The results of the experiments show that when the circumferences of the rolls are speeded for steel in the proportion of 14 to 11 faster than for iron. The power required for steel is about three times more than for iron. The author considers that rolling-mill engines are often made unnecessarily large; he recommends the proportions adopted by Van den Kerkhove of Ghent, whose engines are single-cylinder non-condens-

ing, with Corliss valve gear: the cylinder diameter is 914 mm. (36 inches), stroke 1,524 mm. (5 feet), revolutions per minute seventy-five, and weight of fly-wheel 50 tons. These engines indicate 800 HP., with 60 lbs. steam cut-off at half stroke.

ORDNANCE AND NAVAL.

ARMOR-PLATE TRIALS IN FRANCE.—M. Francis Laur writes:—Experiments have recently been made at Gavres with armor-plates by three different firms—Creusot, Chatillon-Commentry, and Terrenoire. The experiments were conducted upon the same basis as former ones, reported in the columns of *Iron*. The only alteration was the dimension of the plates. Instead of the usual dimension of 4 square meters, the plates were only 1.20 meters square, the members of the commission being desirous to know if the smallness of the plates had any relation to the cracks usual with the largest plates. The results were the following:—

Creusot.—Steel plate (hammered). Penetration, 90 millimeters; slight cracks; excellent results.

Chatillon-Commentry.—Steel Plate Penetration, 320 millimeters; plate shattered in eight pieces; bad results.

Terrenoire.—Compound plate, manufactured without hammering or rolling of the steel, the molten steel being poured upon an iron plate. Penetration, 94 millimeters; cracks slightly more apparent than in the Creusot plate; good results.

The results of these trials are ascertained to be a great victory for Creusot. It will be remembered that at the last experiments, eighteen months ago, the steel plate of Creusot behaved so badly that the failure seemed past remedy. The compound plate of Messrs. Ch. Cammell obtained, on the contrary, a splendid success, and the Marine Department accordingly resolved to protect three ships with this new product, the Aciéries de la Marine, Chatillon-Commentry and Messrs. Marrel Frères being entrusted with its manufacture. These last trials have put a new aspect upon the question, The claim for superiority is now undecided between steel and the compound plates, but I think the question must soon be solved when these last-named will be tested.

THE "DETECTOR."—An exceedingly useful experiment is to be shortly carried out on board the "Sultan," armor-plated ship at Portsmouth. As is well known, all the ships which have been recently fitted out have been provided with electric lights for use as torpedo detectors. Many expedients have been tried for the purpose of enabling torpedo craft to approach a ship without being noticed; but though means have been adopted whereby the lights of their funnels and fires have been effectively screened, and the noise of the engines so deadened as to prevent their being heard until the craft have arrived within striking distance, it was found impossible to conceal the torpedo craft from the searching power of the electric beam, whatever color their hull is painted. It has been found, however, that the "detector," whether placed forward or on the bridge, is itself assailable, and the remarkable precision and range which have been developed by the Nordenfeldt and other machine guns have made it absolutely necessary that both the electric light and the men working it should be placed under protection. The experiments on board the "Sultan" will be undertaken with the object of ascertaining whether it be practicable to use reflected light. For this purpose the detector will be placed below, and the light projected through a tube upon a concave mirror which will be fixed on the bridge above, or on the mast, if necessary, and which will, by means of a pivot arrangement, be able to sweep the water in all directions. The electricity will be generated by a D-Gramme machine, and various lenses will be tried.

THE GREAT GUN TRIALS.—The repair of the hydraulic gear of the 100-ton experimental gun at Woolwich, which was thrown out of order on the first day's trial, was completed in time to permit the members of the Committee on Ordnance to resume the trials last Friday. The charge of powder was again 450 lbs. nominally, but actually only 448 lbs., the four cartridges of which it was composed being made up of precisely 112 lbs. each, for the convenience of the Royal Laboratory. For the manufacture of the prismatic kind of powder which has been adopted for these 100-ton guns, the Government pay upwards of 1s. per lb., and the addition of the shot, crushers, &c., brings the cost of each round up to the sum of probably £30, which is one of the reasons why the committee have been restricted to five rounds only. The three remaining of these were fired without a moment's pervertity. Five-and-twenty minutes were occupied in loading and preparing for the first round, twenty minutes in the case of the second, and fifteen minutes for the third, making exactly one hour occupied in the whole three rounds. This was performed in no way as a time test, for no official time was taken, and there was an entire absence of haste. In an emergency the gun can be readily fired the same number of rounds in less than a quarter of the time, but as a deliberate experiment, liable to many delays, the expediiion used at the trial was satisfactory. In actual service the guns of this size are never likely to be fired rapidly, one well-directed shot being sufficient to dispose of the strongest ironclad afloat. Major W. H. Noble, one of the artillerists on the committee, calculated that the 2,000 lbs. shot fired with a velocity of 1,570 feet per second would strike with an energy of 33,500 foot-tons at the muzzle, which, even at a mile range, would make short work of 3-feet armor. It was held to be remarkable that all this potentiality is generated with so little strain upon the gun, the pressures created by the improved powders being uniformly below 15 tons to the square inch, as was clearly demonstrated by Captain Hemans, R.A., the proof officer. Until recently 25 tons was the standard of security, and the reduction of pressure is most advantageous in facilitating the employment of large

charges, or even, if necessary, sacrificing something of a gun's strength. That the charge of the 100-ton guns cannot be extended beyond 450 lbs. was evidenced by the number of fragments of unconsumed powder picked up in front of the butts, but it is believed that by lengthening the barrel or increasing the bore—already 17¾ inches in diameter—a much larger quantity of powder could be profitably burnt inside the gun. Electricity was employed to ignite the charges, the battery being in the instrument room a quarter of a mile distant. The shots buried themselves in the sandbank to a depth of 60 feet, but the great gun was so perfectly under control that it recoiled only four feet, the hydraulic compressors acting most effectually in absorbing the superfluous force. Now that the experiments are completed, nothing remains but to convey the guns to their destinations in the Mediterranean fortresses; but the War Office has directed that the experimental weapon shall remain where it is for a short time, while the committee consider the results they have obtained, make their deductions, and report thereon.—*Iron.*

BOOK NOTICES.

Publications Received.

We are indebted to Mr James Forrest, Secretary of the Institution of Civil Engineers, for the following published papers of the Institution;

The Tide Guage, Tidal Harmonic Analyser, and Tide Predicter. By Sir William Thomson, LL.D., F.R.S.

Torpedo Boats and Light Yachts. By James Thorneycroft, M.I.C.E.

Description of a Bucket Dredger at the Hull Docks. By Robert Aspland Marillier, M.I.C.E.

Caissons for Dock Entrances. By Daniel Macalister.

Internal Corrosion of Cast Iron Pipes. By Mathew Buchan Jamieson.

On the Construction of Electro Magnets. By Paget Higgs, LL.D.

Three Systems of Wire Rope Transport. By William T. H. Carrington, A.M.I.C.E.

Railway Springs. By Benjamin Baker, M.I.C.E.

The production of Paraffin and Paraffin Oil. By Richard Henry Brunton, M.I.C.E.

Rapport du Chevalier Baillairge, Ingenieur de la Cite de Quebec, sur l'amelioration de son Aqueduc.

Instructions for Transmitting Communications by Heliotrope Signalling, arranged for use on the New York State Survey. By Olin H. Landreth.

Transactions of the American Institute of Mining Engineers.

New Method of Mapping the Anthracite Coal Region. By Charles A. Ashburner, Assistant Geologist.

Annual Report of the Operations of the Engineer Department of the District of Columbia. Under direction of Major W. J. Twining, U. S. Engineers.

History of the Cincinnati Waterworks. By Thomas J. Bell. Cincinnate: Robert Clarke and Co.

Contributions to the Theory of Blasting in Military Mining. By H. Hofer; translated by Captain Charles W. Raymond, Washington Government Printing Office.

Traite de Mecanique Generale. Par H. Resal. Tome Sixieme. Paris: Gauthier-Villars. Price $5.25.

This last volume of Resal's excellent work is devoted to practical engineering. The subjects treated are—Voussoir Arches, both Right and Oblique, Framed Wooden Bridges, Iron Bridges, Suspension Bridges, Draw Bridges, Chimneys, Foundations, Interior Navigation and Harbor Improvements.

Each of these topics is fully treated and beautifully illustrated; these latter, moreover, are designed especially to aid the engineer in comprehending the details of the construction. The cuts in this volume alone are more than five hundred in number, without including several large colored plates illustrative of European harbors.

Celestial Objects for Common Telescopes. By Rev. T. W. Webb. M.A., F.R.A.S. Fourth Edition greatly enlarged. New York: Industrial Publishing Company. Price $3.00.

The former editions of this are well known and highly valued by amateur astronomers. A full list of stars and nebulæ that are within range of ordinary telescopes is given, with the means of treating each object.

Epuration de la Houille, Criblage, Triage et Lavage. Par A. Burat. Paris: J. Dejey and Cie. Price $5.25.

This quarto volume is devoted to the various processes of cleansing, screening, and otherwise preparing coal for the market and for use.

Ten large folding plates exhibit the various machines on a scale sufficiently large to show most of the details.

This subject has only recently been regarded of sufficient importance to be made the subject of a separate treatise. But the numerous inquiries that have been made of late in reference to the best methods of coal working and separation have revealed the fact that the various processes have now assumed the importance of true engineering operations. The volume before us bears convincing evidence that nothing short of engineering skill of a high order could successfully design and operate such works as are described in it.

Practical Boat Building and Sailing. By Adrian Neison, C.E.; Dixon Kemp, A.I. N.A.; and C. Christopher Davies. Price $2.80.

The first of the subjects comprehended in the above title is treated by the first two of the trio of authors, and sailing, to which two-thirds of the treatise is devoted, is the work of Mr. Davies.

Throughout both treatises a plain and graphic method of instruction is employed, and the illustrations are very good and very abundant.

Sailing Rules of the London Sailing Club and of the Yacht Racing Association are given in an appendix.

ELEMENTS OF QUATERNIONS. By A. S. Hardy, Ph.D., Professor of Mathematics, Dartmoth College. Boston: Gunn & Heath. Price $2 50.

To any one who has labored with the very few works extant upon this branch of mathematics, a glance at the opening chapter of Prof. Hardy's work will enforce the conviction that the author is an instructor of the first order.

We now have for the first time a text book on quaternions, which the student of only ordinary mathematical ability can read with satisfaction and profit.

The book is quite opportune. The subject must soon become a necessary one in all the higher institutions, for already are writers of mathematical essays making free use of quaternions without any preliminary apology.

It is safe to predict an eager acceptance of this work, among mathematical students throughout the country.

THE ANEROID: ITS CONSTRUCTION AND USE. Science Series No. 35. New Edition re-written and enlarged. New York: D. Van Nostrand. Price 50c.; full roan, $1.00

The demand for this little manual exhausted the first edition.

The present volume is larger, and includes important additions.

The construction of the different kinds of aneroids is illustrated by cuts and text. The errors which are commonly made in using these instruments, and the means whereby the best results are obtained, are made matters of special treatment.

Numerous examples are worked out as aids to the novice in employing formulas and tables

Two tables, not in the former edition, appear in this; a metric altitude table and a table of boiling points and corresponding barometric heights.

The increasing use of the aneroid warrants the belief that this book will be widely read.

THE SUN. By C. A. Young, Ph.D., LL. D., Professor of Astronomy, College of New Jersey. New York: D. Appleton & Company.

This is at the present time the latest issue of the International Scientific Series. Price $2.00.

American people have just reason to be proud of the fame of Dr. Young. His labors with the spectroscope, resulting in many important discoveries, have made his name familiar wherever there are astronomers or astronomical students.

The progress made in the study of the corona, in which the author first achieved distinction, is made the subject of an interesting chapter.

The typography and illustrations are of the same high degree of excellence exhibited in previous volumes of the series.

SECOND GEOLOGICAL SURVEY OF PENNSYLVANIA: SPECIAL REPORT ON CAUSES, KINDS AND AMOUNT OF WASTE IN MINING ANTHRACITE. By Franklin Platt.

The Legislature of Pennsylvania at its last session passed a joint resolution to the effect that an inquiry be made into the causes of the rapid exhaustion of anthracite—the possibility of more economy in the methods of mining, and the avoidance of the great waste and over production now prevalent.

The subject of *waste* in mining and subsequent handling is specially treated in the present Report. The result of the inquiry, though long known to mining engineers, will prove a surprise to the public generally. Not more than one-third of the coal lying in the ground can ever be brought to market by present methods of working and transportation.

The maps submitted with this report require a special mention. The method here employed of representing underground deposits was originated by Prof. Lesley, and was made the subject of an interesting paper before the American Institute of Mining Engineers, by Mr. Charles A. Ashburner, Assistant Geologist of the Survey. By this plan a geological mining map will represent:

1. Elevation above tide of the coal outcrop.
2. Dip of the bed.
3. Strike of the bed.
4. Depth of the coal basins.
5. Rate of rise or fall of basins along their axes.
6 Position of synclinals and anticlinals in the coal bed.
7. Data from which a vertical section may be made.
8. Data from which the absolute surface area of the coal bed may be obtained, and the tonnage of any section estimated.

A full description of the method, with examples of the maps are given in Mr. Ashburner's paper, which is published in a neat pamphlet.

MISCELLANEOUS.

A MIDGET MOTOR.—A little curiosity in engineering has been constructed in America by an ingenious clockmaker, Mr. D. A. Buck. This is in all probability the smallest steam engine in the world, for it is almost microscopic in its dimensions. The whole machine weighs only about a gramme, or 15 grains, and is entirely covered by an ordinary thimble. The stroke of the piston is a little over 2 millimeters or $\frac{1}{12}$ inch, and its diameter is something less than a millimeter and a half. Nevertheless it is built up of 140 distinct pieces fastened together by 52 screws; and three drops of water suffice to fill the boiler, and set the toy mechanism in motion.

CAPTAIN ABNEY recently exhibited at the Physical Society of London a number of photographic negatives taken by himself and Colonel Festin by radiation through thin sheets of ebonite. The light from the positive pole of an electric lamp was sent through a sheet of ebonite $\frac{1}{24}$in. thick, and photographs taken

showed the radiation to have a low wave length from 8000 to 14,000. The carbon points of the lamp could be photographed through the sheet, and Colonel Festin observed the sun's disc through it. The ebonite showed a grained structure, and different samples of ebonite gave different results, but all gave some result, in course of time at least; old ebonite, like that used in some of Mr. Preece's experiments, scattering the light more than new ebonite.

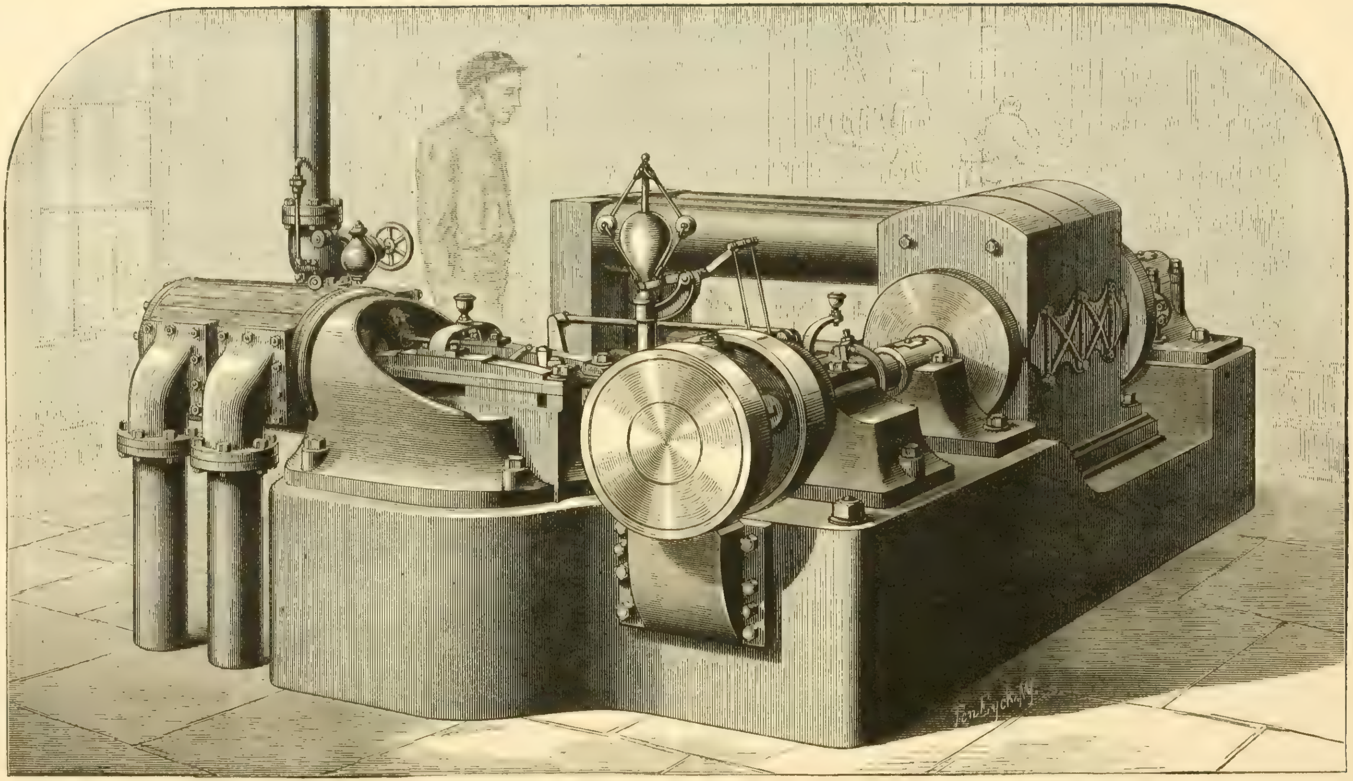
At a recent meeting of the Paris Academy of Science, a memoir on the temperature of the air at the surface of the ground and down to 36m. depth, also the temperature of two pieces of ground, the one bare, the other covered with grass, during 1880, and of the penetration of frost into these, was read by MM. Becquerel. Amongst other things the propagation of frost is shown to be slower in grassy ground than in bare ground. In the latter the rate increases very slightly with the depth, the propagation being very regular. In grassy ground the increase is very notable, and with increasing depth, the rate tends to come near that in bare ground. Each layer of ground is subject to two calorific effects; one due to variations of external temperature; the other to the action of deep layers which tend to give a constant temperature.

The influence of pressure on the electric conductivity of metal wires has been studied anew by M. Chwolson, and described in the bulletin of the Imperial Academy of St. Petersburg for March. M. Chwolson used a piezometer, giving pressures up to 60 atmospheres, the wire being wound round a glass tube, then passed through it, and the tube inserted in another, which was connected with the piezometer. The two wire ends were brought out through binding screws. Among the results at 3.8 C, the copper wire showed a relative diminution of resistance of about 0.0000013 by one atmosphere of pressure; a hard brass wire about 0.0000011;and a lead wire (at 7 deg. C) about 0.000011, or ten times more than brass. Pressing at 17 deg. C. the calorific action preponderates over the direct action of pressure for copper and brass, while the reverse occurs with lead. Moreover, the author proves, in the case of the brass wire, that the pressure causes change of the specific resistance, besides change of the resistance, through change of the length and thickness. Every relative change of volume involves a relative change of the specific resistance about 3.6 times as great.

One of the recently introduced substitutes for gold, which has become very popular in some of the jewelry and other manufactories of fine wares in France, is composed as follows: 100 parts, by weight, of copper of the purest quality, fourteen of zinc or tin, six of magnesia, three and six-tenths of sal ammoniac, limestone, and cream of tartar. The copper is first melted, then the magnesia, sal ammoniac, limestone, and cream of tartar in powder are added separately and gradually. The whole mass is kept stirred for half an hour, the zinc or tin being dropped in piece by piece, the stirring being kept up till they melt. Finally, the crucible is covered and the mass kept in fusion thirty-five minutes, and the scum being removed, the metal is poured into moulds and is then ready for use. The alloy thus made is represented as being fine-grained, malleable, takes a high polish, and does not easily oxidize.

When making some experiments under the direction of M. Chevreul, M. Niepce de St. Victor, who tried helio-chromic experiments on a large doll bedecked with jewels and resplendent with colored silk, made the remarkable discovery that black is not the mere absence of light, but is entitled to be considered a color of itself, and has a special chemical action of its own. The color of the sensitive plate was violet, and on this the camera impressed all the colors of the doll, including white; but as the blacks had also been impressed as black, it led to this experiment: A hollow tube, black from the absence of light, was presented to the camera, together with another article of a definite black color, with this result, that the former was represented by an unaltered state of the original violet color of the surface, while in the latter case a very deep black resulted.

Some extensive and important brake trials are in progress on the German State Rail ways. The brake question has long been receiving thorough examination by the German Government, and recently, in addition to numerous trains running ever since the Cassel brake trials in 1877 on various lines, trains have been specially prepared, fitted with the following six continuous brake systems, the inventor or his representative being in each case called upon to certify in writing that the vehicles are supplied with the most recent improvements :—Heberlein, Smith Hardy, Sanders, Westinghouse, Steel McInnes, and Carpenter. A series of trials on a portion of line near Halensee Station, on the Berlin Girdle Railway, will commence about the 29th inst., before a commission of engineers specially appointed to report on the subject of continuous brakes. The most practical portion of the trials will, however, commence immediately afterwards, when all six trains will be sent to work the express service between Berlin and Breslau for three or four months. The ordinary hand brakes on the vehicles are to be *plombe*, so as to ensure that in each case the special system on trial is alone used for all purposes, the cause of any departure from this rule, as well as any inconvenience or delay whatever in the usual traffic of the line resulting in any measure from the continuous brakes, being specially noted by an engineer told off to accompany each train throughout its journey. Captain C. Fairholme, in a letter to the *Times*, says : "The extreme care taken by the authorities of the Royal Railway Direction of Berlin, to whose charge the control of the entire arrangements has been committed by the Minister of Public Works, to ensure perfect impartiality, as well as the known high character of the German officials generally, combine to give these trials a special interest."



EDISON'S STEAM DYNAMO.

VAN NOSTRAND'S

ENGINEERING MAGAZINE.

NO. CLVI.—DECEMBER, 1881.—VOL. XXV.

INCANDESCENT ELECTRIC LAMPS AT THE INTERNATIONAL EXHIBITION OF ELECTRICITY.

BY THE COUNT DU MONCEL.

Translated from "La Lumiere Electrique."

In a previous article* we indicated in what case this system of Electric Lighting was specially applicable, and we saw that henceforth, thanks to important improvements recently introduced, it could be employed for the interior of houses, where light of feeble intensity is used; we have seen that several castles in England were lighted in this way, and that a certain number of houses in the city of New York had subscribed for the light furnished by the Edison Electric Light Company. Since the successful introduction of these lamps a great number of systems of the same kind have been brought out by different inventors, and without speaking of such well known ones as those of Edison, Swan, Maxim, Lane, Fox, Sawyer, we know of about fifteen inventions, bearing more or less upon the subject. It, therefore, seems to us an opportune moment to enter into circumstantial details about this method of lighting, which, up to this moment, has not excited any great interest in Europe, for various reasons which we have enumerated in different articles published in this journal at the commencement of the year 1880, of which the principal one was the relative considerable expenditure of motive force to produce a light of given intensity. It should be borne in mind that the luminous power of an incandescent body increases in a much greater ratio than the calorific intensity; therefore, by the very fact that incandescent lamps permit a greater division of the electric light, a loss is caused by the weakening of the radiating power resulting from the same. Nevertheless, the satisfactory results recently obtained force us to pass these systems of electric lighting in series, and we will begin naturally enough with that of Mr. Edison, which has made the most noise in the world, and which has attracted attention to this manner of lighting by electricity.

EDISON'S SYSTEM OF ELECTRIC LIGHTING.

The incandescent system was first represented by lamps made from an incandescent platinum wire, and the interesting experiments made in 1879 by M. de Changy, should be recollected; but the practical workings of this system were not satisfactory, principally because of the disaggregation and partial fusion of the wires, and in spite of the numerous improvements brought to bear on this system by Mr. Edison, who, by one of the most ingenious of processes, had rendered them

* "La Lumiere Electrique," Aug. 20, 1881.

more infusible and harder, still they had to be absolutely rejected—at least for ordinary lamps. Then it was suggested to employ carbon which, if not allowed to burn, is infusible in the highest heat developed in the lamps, and different arrangements of apparatus were put together at various times by King, Lodyguine, Bouliguine, Swan, Sawyer, etc., some avoiding combustion by enclosing the lamps in receptacles where a vacuum had been obtained, others by filling these receptacles with gases unfit for combustion, as nytrogen or oxide of carbon, or simply by leaving the air shut up in the receptacle to be vitiated by an incipient combustion.

All these attempts had but partially succeeded, to say nothing more, when, in 1879, the new incandescent carbon lamp of Mr. Edison was announced, and many savants, and myself in particular, doubted the exactness of the allegations which came to us from America. The carbonized paper horse shoe appeared incapable of resisting mechanical shocks, and of supporting incandescence for any length of time. At this epoch Mr. Swan himself said that up to that time he had not been able to obtain any very satisfactory results by an analagous disposition of the incandescent organ.

Mr. Edison, however, was not abashed, and in spite of the lively opposition made to his lamps, in spite of the bitter polemic of which he was the object, he did not cease to perfect it for practical purposes, and has at last produced lamps, which we have seen at the Exposition, and which can be admired by all the world for their perfect steadiness. These lamps, to the number of 160, light the two salons reserved for the discoveries of the ingenious American inventor, and we shall see still more important results upon the installation of the great machine which is expected from America.

As at present made, these lamps are sufficiently solid and can last a long time. The originally fragile carbon has become extremely elastic and hard, and of such attenuation that it can be well compared in size to a horse hair. By a cleverly combined system of fastening the platinum, conducting wires are not exposed to be cut, and they are so sealed in the glass receiver that their change of volume under the action of heat does not endanger the perfection of the vacuum. By the way the carbons are treated when the vacuum is made in the globe, the bubbles of air enclosed in their pores and which, in escaping, disaggregate the surface, are evacuated before closing the lamp, and at the same time the filament of carbon acquires a peculiar density and hardness, as was the case with the platinum wires. To obtain this result the carbonized filament must be brought into incandescense while the vacuum is being made. The very nature of the substance of vegetable origin employed in its fabrication, has been modified.

Fibers of bamboo are now used instead of the paper originally employed. These are carbonized by a certain process, and the successive transformation of these fibers into carbon filaments may be followed in several collections to be seen at

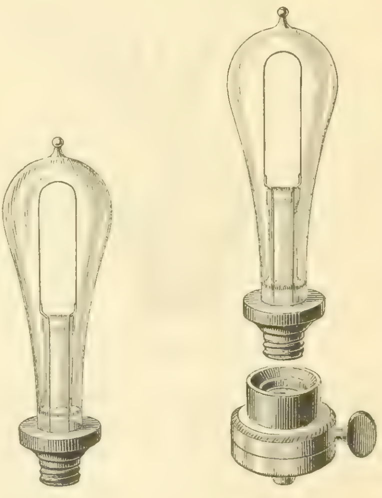


Fig. 1. Fig. 2.

Mr. Edison's exposition, and which will gratify the curious, and are worthy of study. According to Mr. Batchelor and Mr. O. A. Moses, co-laborers of Mr. Edison, and who represent him at the exposition, the resistance of these filaments is 125 ohm, when brought up to an incandescence corresponding to 16 candles; but it can vary according to the luminous power desired of the lamps, for it can be distributed between two lamps, whose filaments are correspondingly more or less long. Their extremities, which are

enlarged, are pressed in a kind of pincer which terminates the platinum conductors, and which are soldered by an electrolytically deposited copper. Figs. 1, 2, 3 and 4 represents the actual arrangement of these lamps. Their duration, from what I have been assured, is long enough; however, they must wear out. Although most of them may have served for 1,200 hours, the question may be asked whether a lamp capable of deterioration may be considered a practical thing; but if it is considered that this lamp can be furnished for 30 cents, that the adjustment on its support cannot be any simpler than

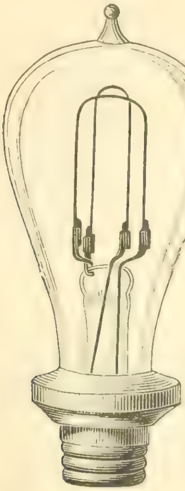


Fig. 3.

it is, which is evident on inspection, it is easily seen there is no more trouble to replace one than to renew a broken lamp shade.

What constitutes Mr. Edison's system is not alone his lamps, it is the totality of the arragements referring to them and which have attained such a degree of simplicity that henceforth nothing remains to be desired in practice. Generating machines, distribution of circuits, installation, indicating and regulating apparatus, meters for measuring the amount of current employed are all combined for immediate application. As we have said, this application is about being made in a part of the city of New York, where a great number of houses are to be lighted by this system, by means of a subterranean distribution from a central station, from which also motive power will be distributed to the houses.

This central station will be provided with twelve steam engines of 150 horse power each, actuating dynamo-electric machines, each of which will be capable to supply, it is said, 2,400 lamps of 8 candle power. The current furnished to these lamps comes through a branch taken before each house from the large-sized conductors laid in the streets. These deviations bring the poles of the

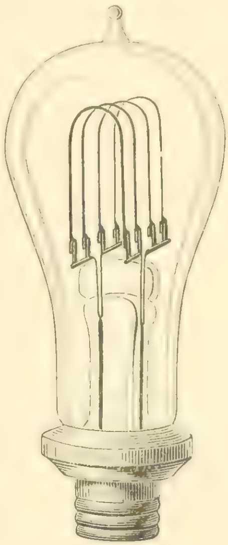


Fig. 4.

generator into each house, where the lamp wires can be brought in connection with them, thus rendering each house independent of any other, both for a supply of light and motive power.

When it is considered that the system of distribution adopted by Mr. Edison, the total resistance of the exterior circuit is extremely reduced and that with 2,400 lamps it is only $\frac{64}{2.400}$, say, about .026 of an ohm, it can be seen that a very feeble resistance should be given to the generating machine; so that its first arrangement has been modified. To begin with: The field magnets were arranged on a derivation taken from the commutator, putting it into the induced circuit as in Wheatstone's and Siemens' system. Then the armature was arranged on Sie-

mens' principle, so that the wire consisted of bars of copper. These bars lie close to each other around the cylinder which forms the armature, and they generate the current. Their extremities correspond to discs of copper (at right angles to them) laid one against the other at the ends of the cylinder, and insulated from each other. Each bar is fastened to its corresponding discs in such a way as to form a single circuit enveloping the cylinder longitudinally, and which is made perfect through the coupled bars two and two with the commutator blocks (made after the Grammes pattern). Figs.

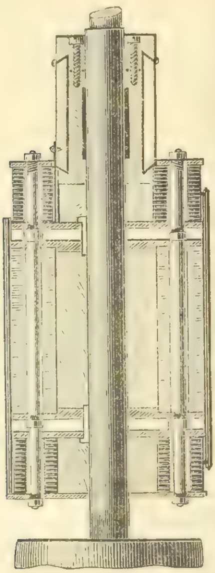


Fig. 5.

5 and 6 give an idea of this new arrangement. The center of the cylinder itself is occupied outside of the rotating axle by a cylinder of wood, which, in its turn, is surrounded by a thick tube made of a series of very thin discs of iron, separated from each other by tissue paper. This arrangement facilitates the rapid changes of polarity in the plates. This tube is terminated at its two extremities by two thick clamping discs which are made to compress the others lsterally, and the copper discs of the working coil occupy the two compartments at the extremities of the cylinder, as seen in Fig. 5. Under such conditions as these the resistance of the generator is small, and permits of great subdivision of the current in multiple arc; nor is there any insulation to be burned, and it is even possible, in case of the deterioration of the bars, to renew them easily, for they are simply screwed against the copper discs corresponding to them. In the new disposition adopted by Mr. Edison, the field magnets lie horizontal instead of being placed in the vertical.

Fig. 7 represents the whole machine as now actually working in the Palais de l'Industrie.

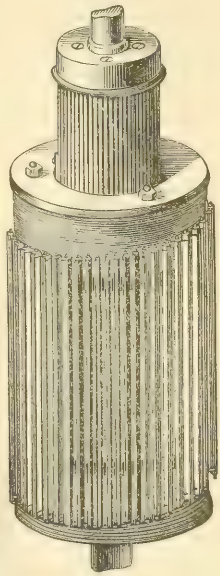


Fig. 6.

We have described the generating machine before completing the description of the system of distribution of the current, because we ought to speak of the system of control used in making the current uniform when its intensity has been modified by a variation in its distribution; that is to say, following after a variation resulting from the unexpected suppression of a certain number of lamps in a part of the system. The necessities of this system are easily understood, if we consider that this suppression can lead to a greater or less increase in the intensity of the current feeding the remaining lamps.

In France several systems have been

devised to obtain an automatic regulation, but in America, it seems, it is preferred to effect this by the intermediation of an appropriate controlling agent.

In this system, in whose general arrangement we see, in Fig. 8, the current sating for it should be introduced into the circuit. Mr. Edison has established a circular commutator *e* with bobbins of different resistance, which permits of an increase of resistance, not in the lamp circuit, which would lead to a loss of

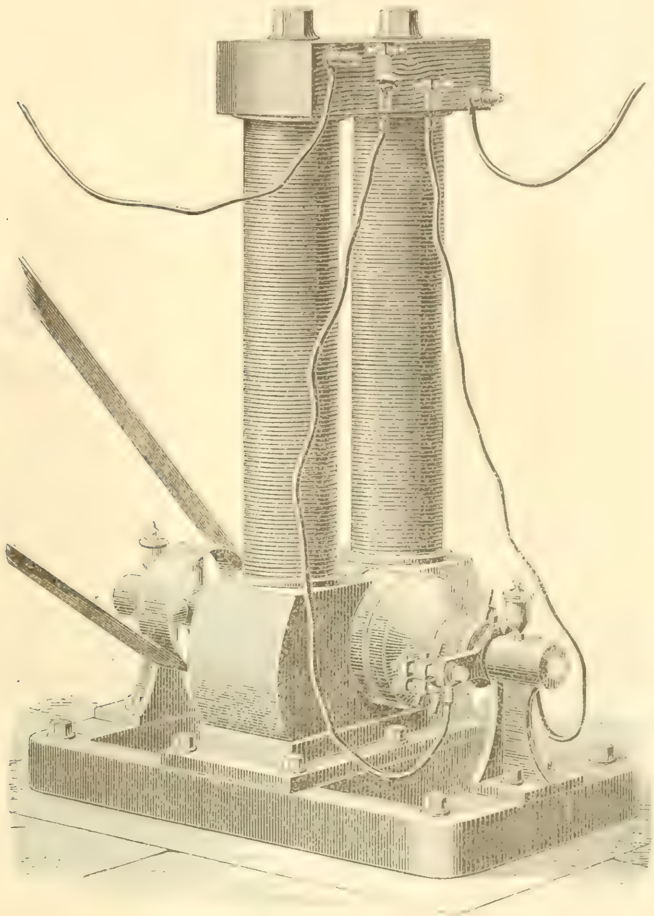


Fig. 7.

which feeds the lamps furnishes a deviation at the machine *cc*, which enters an electric dynamometer, after having gone through a resistance of 180,000 ohms. The electro-motive force should be about 110 volts, and a difference of one volt should correspond on the scale of the indicating apparatus to three divisions; consequently, for each observed increase of intensity a resistance capable of compen- work, but in the circuit of field magnets, which weakens their action on the working coil. From the central station also, the condition of the current affecting the lamps can be controlled by means of a testing photometer, which enables us to see how much the intensity of the current must be diminished or increased to correspond to a given luminous intensity. For this purpose the photometer is

mounted on a little railroad, placed in a dark chamber; under and in front of it is placed a scale, arbitrarily divided, so as to indicate immediately the candle

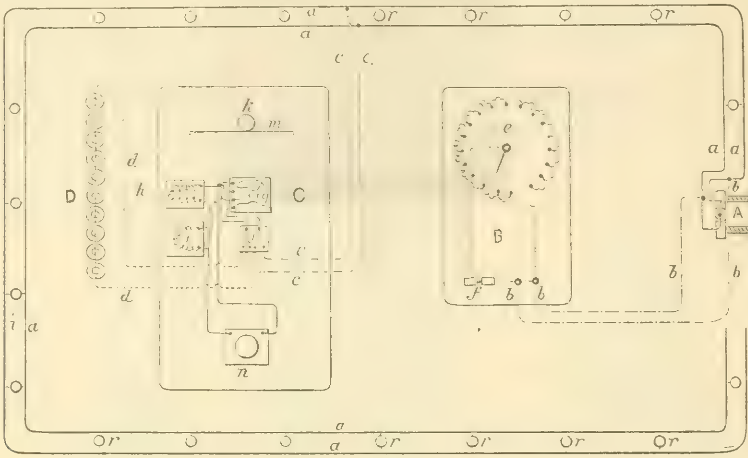


Fig. 8.

power furnished by the current in its normal condition. The left side of Fig. 8 indicates the manner of arrangement of the testing bench, with the explanatory

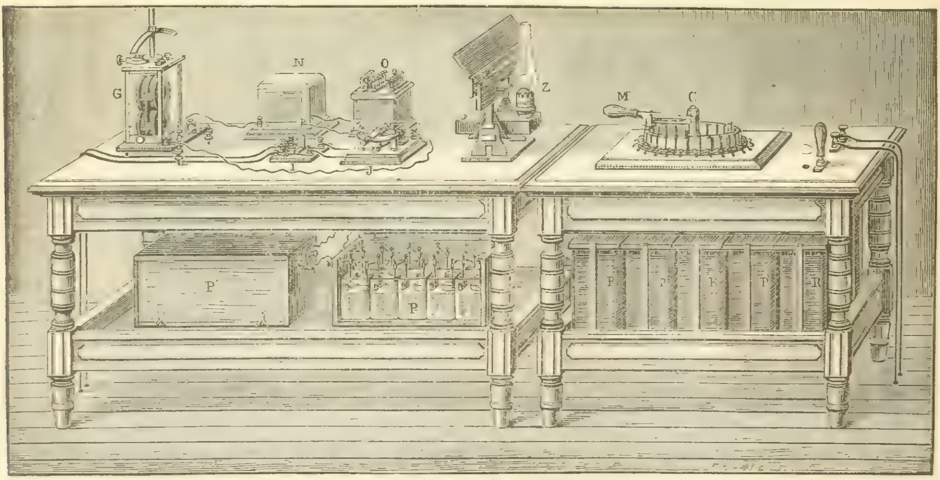


Fig. 9.

able at the bottom of the figure. Fig. 9 shows it in perspective. The manner in which derivations are taken on the principal conductors merits especial mention. The conductors are composed of two rods of copper of hemi-cylindrical form, flat on one side and round on the other, which are enveloped in cylinders of insulating material, contained in small wrought-iron pipes, which are buried under the streets. To take a derivation the cable is laid bare at the spot where the branch circuit is to be established. The two conducting rods (coming from the main conductors) are cut and bent outwards and introduced into a clamp where they are soldered to the house wires, as shown in Fig. 10; but in order that no harm can be

done by two strong currents, one of these communications is made by intercalating a lead wire in the branch circuit, shown at the bottom of the figure, and which, by its fusion, interrupts the circuit. This is what is called in America a "cut off;" and in this way it prevents deterioration. The box is then hermetically closed and covered with an insulating coating. In the figure the branch wires are shown double, but it is evident that they could be single.

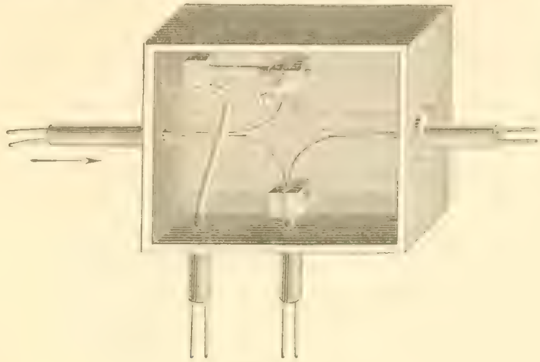


Fig. 10.

We said that all arrangements had been made to make the system a perfectly practical one, and of that we will soon be able to judge. Let us examine first how the lamp supports and the lamps themselves are disposed. As has been seen, they are formed of glass globes of ovoid form, cemented into copper sleeves by means of plaster and screwed into cylindrical cavities terminating the supports. These are a kind of arm which can be adapted to brackets or chandeliers, or be arranged around the walls. In the last case, the arm as is shown in Fig. 11, carry two articulations, A and B, and commutations are made by two plates of the hinges which are insulated, and in whose circular part two springs press, as seen in Figs. 12 and 13. Connections of the conductors with the lamp, as we have indi-

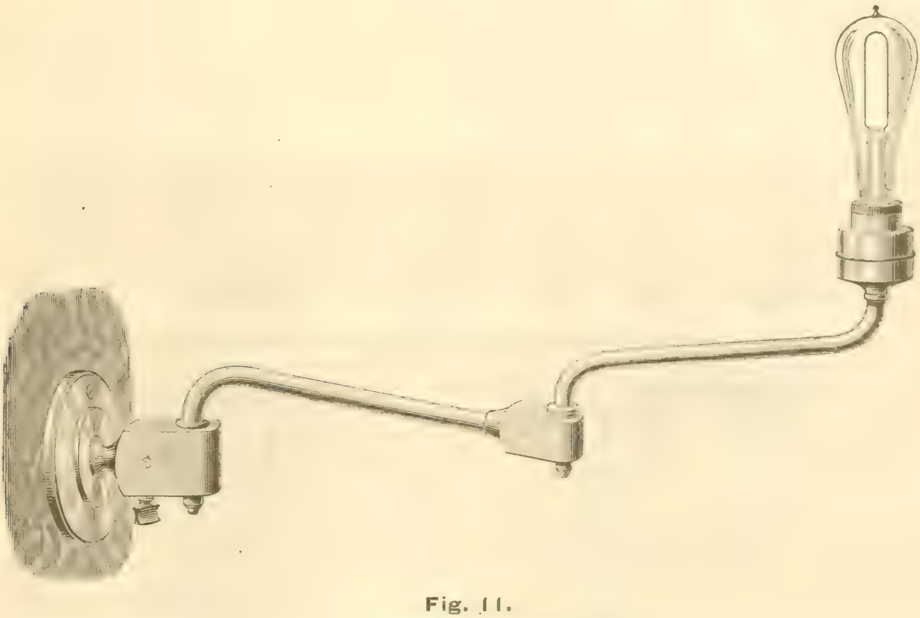


Fig. 11.

cated above, are made by a lead wire (cut off) which may melt and interrupt the circuit in case a too great quantity of current should endanger the lamp.

In these brackets, as in the three branch chandeliers, represented in Fig. 14, keys have been introduced which allow the extinction of the lamps separ-

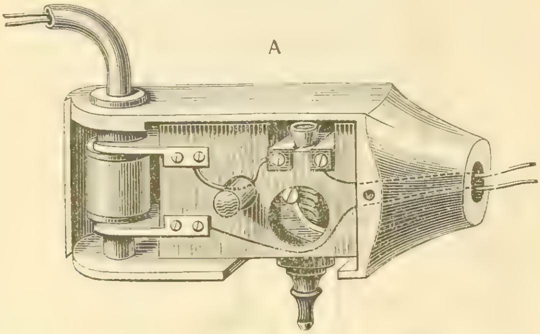


Fig. 12.

ately or together, without causing any spark of the point of rupture or any danger of fire. The movement of the key *a*, as shown in Fig. 12, breaks the contact by means of a conical stopper which terminates the screw of the key, and which, when separated from the two plates, through which the current passes when the stopper is in contact with them, breaks the circuits at the points and on

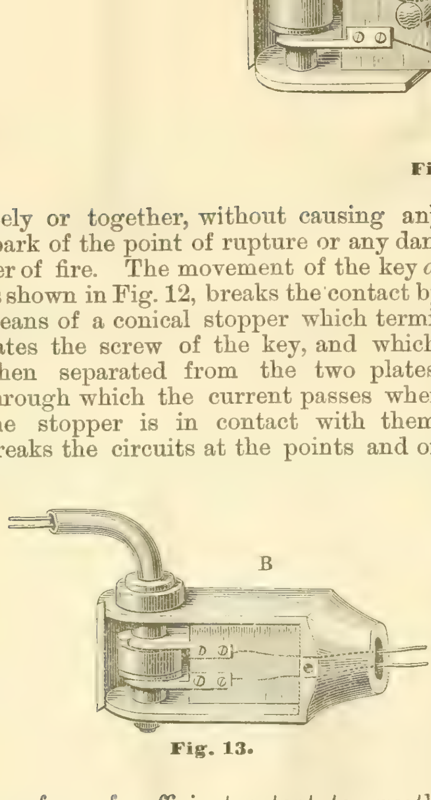


Fig. 13.

a surface of sufficient extent to greatly diminish the spark at the point of rupture.

The lighting of the two salons of Mr. Edison at the Exposition is done by 16 small chandeliers like the above, two grand crystal chandeliers and 80 brackets.

The effect is very beautiful, the steadiness being as complete as could be desired, and if, as I have been assured, the price of this kind of illumination is lower, light for light, than gas, it may be considered that the problem is on the eve of solution, for Edison's system of electric lighting is placed in the same condition as that of gas. He avoids the presence of machines in separate houses, which always are in the way, and which, by their very nature, require care and management not to be obtained from ordinary servants.

As a complement to his system, Mr. Edison has constructed portable chandeliers, represented in Fig. 15, and a current regulator shown in Figures 16 and 17, which permits of reducing the light in any desired proportion. It is a carbon rheostat, composed of carbon pencils of different sections, which, as the current passes through one or the other, allows any desired intensity. The apparatus is enveloped in a cylindrical cover, pierced with holes to allow of the escape of heat, and surmounted by a lamp which indicates to the eye the desired degree of luminacy. It is worked by a disc, shown separated in the lower part of Fig. 16, and which can be turned so as to bring a contact spring on any one of the supports of the carbon, whose position is indicated by an index and divisions engraved on the base of the cylinder.

But what is most interesting of all in those accessories of Mr. Edison's system, is the meter which determines the amount of electricity consumed by the lamps. There are two kinds, one automatic like a gas meter, the other requires weighing. They are, however, both founded on the same principle, that is to say, in the estimation of work by the

weight of a copper deposit produced by the current used. We will describe these two interesting pieces of apparatus here-

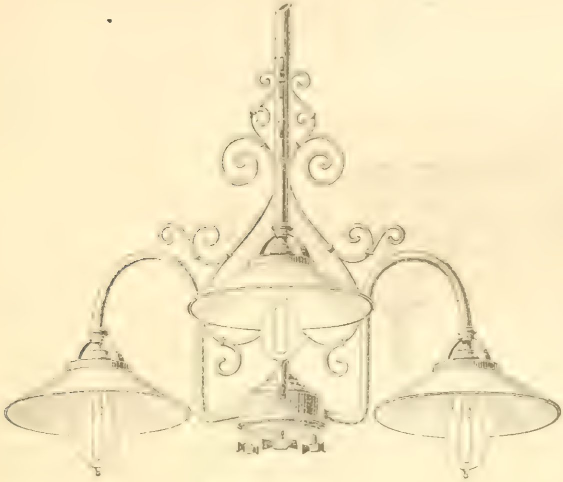


Fig. 14.

after, and give drawings of them; to-day we must be content with only mentioning the principle involved.

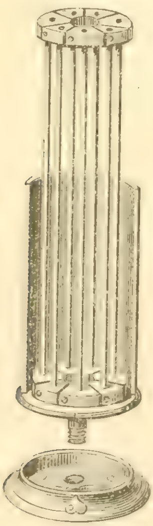


Fig. 16.

Imagine a balance having at the extremities of the beam two cylindrically rolled plates of copper forming two electrodes. Let us admit that these two systems of electrodes, which plunge into two vessels filled with a solution of sulphate of copper and furnished with fixed electrodes,

Fig. 15.

are traversed in an inverse direction by the current employed, and which can cause the balance to operate under a

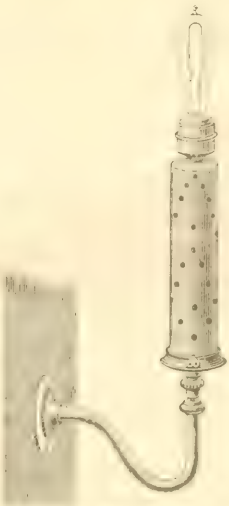


Fig. 17.

given weight of copper deposited from the solution. It is easily seen that the movement brought about by these conditions can set in motion a current re-

verser, which can change the conditions of the deposits in such a way that the electrode, covered with copper, is transformed into a soluble electrode, while the one which was originally in that condition becomes the reducing electrode. From this time on an oscillating motion of the beam of the balance is established, and more or less frequently repeated, according to the rapidity of the formation of deposit, that is to say, according to the intensity of the current. As the same movement can bring about the passage of a derived current (taken from the total current) across a special electro-magnet, which commands the movement of a counter, it is easily seen (after the determination of the number of Amperes corresponding to the weight of the deposit, which produces the oscillation of the balance) what is the quantity of electricity consumed.

The realization of this idea has necessitated some electro-magnetic arrangements, which we will describe in detail when we get the drawings of the apparatus.

The other system is more simple, consisting of two voltameters of sulphate of copper, whose electrodes can be easily taken out and weighed, as the work done can be calculated from the weight of copper deposited. One of these voltameters is open to the subscriber, the other is kept closed by the controller. Resistance bobbins introduced into the circuit corresponding to these resistances, permits of the employment of greater or less periods of registration.

A small incandescent lamp placed beneath the apparatus, and which can be thrown into circuit by a simple metallic thermometer, prevents any danger of freezing in extremely cold weather.

There is another application of Mr. Edison's light, which can be seen at his exposition in a model intended for lighting galleries in mines. In this arrangement, represented in Fig. 18, the lamp is introduced in a glass receptacle filled with water and held in suspension. Communication of the apparatus with the circuit is arranged in such a way that the points of contact are covered by water, which avoids any danger of explosion in mines infested with fire damp.

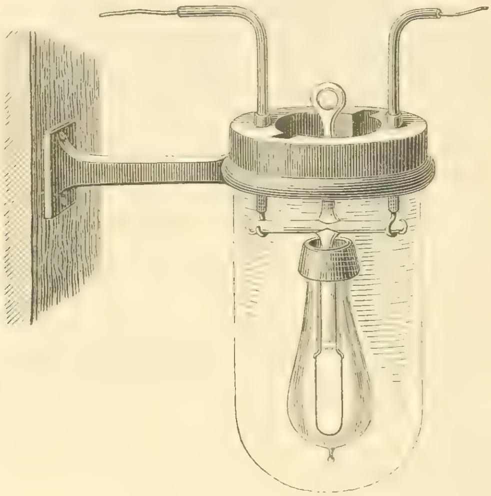


Fig. 18.

To give an idea of the application of Mr. Edison's systems, we have represented in the large engraving accompanying this article, Fig. 19, the interior of a parlor lighted by the small chandeliers previously described. As is seen, the electric light is projected downward, the best arrangement for reading and writing. This method seems to be preferred by Mr. Edison, but as can be seen above described that all styles of illumination can be produced with this kind of light,

analogous to that obtained with candles or gas jets, it is simply a matter of taste.*

Mr. Edison's lamps are not alone employed in the two salons reserved for him, they are to be found in various places throughout the great nave, notably at the exhibits of Messrs. Heilman, Ducommun et Stienben (of which we gave a drawing in a previous article) and at the exhibit of Messrs. Sautter and Lemonnier. At these two places the currents are furnished by two Gramme machines, type A, and each one lights about 40 lamps. Now that Mr. Edison's great machine (a drawing of which is shown on frontispiece) has arrived at the Exposition, it will be possible to obtain, with the incandescent system, illuminations of greater magnitude. The landing of the great staircase will be lit in this way. It is proposed to accomplish this by means of a crystal chandelier of 144 lamps, and of others furnished with 25 lamps each, to be hung from the different panels, and of girandoles standing on the 16 pilasters of the staircase. This will produce an enchanting effect and a brilliant illumination. I am not quite sure that this mixture of arc and incandescent lights is a happy thought. It is evident that the latter destroy the effect of the former, and might lead one to believe that the luminous intensity of the incandescent lamp is less than it really is. Again, the difference in the color of the lights is so contrasted that many persons who reproach the electric for its ghastly aspect, find it too red in incandescent lamps. It is evidently an effect of contrast, for the light of incandescent lamps is whiter than that of gas jets, which, nevertheless, these same people find very agreeable. If required, incandescent lamps can give a dazzling white just as well as the others; it is only necessary to employ a stronger electrical intensity, then they lose their peculiar qualities, that of giving a soft light which does not fatigue the eye and of an easier and more complete subdivion.

It is certainly very difficult to satisfy everybody, and that many persons hardly know what they do want; above all, when the effects of contrast momentarily impair the power of judging correctly. On the other hand, there are certain fault-finding spirits who are never satisfied with anything; witness the author of that incomprehensible article that recently appeared in a certain journal, who pretended that only discordant sounds and puppet-show voices could be heard in the telephones from the opera. The author in question who could perpetrate such an enormity must have had his ear as sick as his humor. The crowd passing every evening before the telephone rooms at the Exposition, is the best proof of the inanity of such judgments, and by this can once more be seen the value of the scientific lucubrations of certain political journals.

The same thing happens with the electric light, and quite a number of persons who, without previous examination, and without being of the same opinion two days consecutively, come to us and disparage electric lighting. It is certain that new inventions have great difficulty in coming to light and in succeeding, above all when they are opposed by rival interests, but when they are really good they triumph in time over all obstacles.

We would like to give some information about Mr. Edison's new machines, but as they are not yet put up we reserve the description for another time; we will only say that the steam engine was constructed especially for this application, that it makes no noise, and that the dynamo-electric machine forms one of its integral parts. The field magnets of this latter-mentioned, in place of being vertical as in the model represented in Fig. 7, is horizontal, and the dimensions of the machine itself are much larger.

The steam engine, which works the machine, is of peculiar construction, and the speed of rotation which is communicated to the working coil is 350 turns a minute. This is not a very great speed, but the armature is very heavy, weighing, as we are told, over three tons and a half. The magnetic field in which it turns is formed by three powerful electro-magets, united so as to form but one at their extremities.* In the salon of Mr. Edison are a collection of photographs, among which may be seen some of the manufactures where the enormous amount of

* For want of time the engraving referred to has not been reproduced. The idea is shown in Fig. 14.

* For description of Steam Dynamo (frontispiece) see end of article.

material required in these installations is constructed. As we have been assured, one of these turns out 2,000 lamps a day, giving occupation to 150 persons. In accompanying drawings and collections can be seen methods of glass blowing, the carbonizing of the filaments intended for incandescence, the vacuum pumps and the mounting and packing of the lamps. The pumps referred to are set in motion by dynamo-electric machines.

From all this, we see Mr. Edison's system to-day is completed, perfectly studied out in all its parts, and that nothing more remains to be done, but to introduce it on a great scale.

TH. DU MONCEL.

[Note by the Translator.]

DESCRIPTION OF EDISON'S STEAM DYNAMO.

(*See Frontispiece.*)

Peculiar to the Edison system is the idea of connecting an engine of great power directly to the armature shaft of a single dynamo, capable of absorbing the full power of the engine, and of economically converting the same into electrical energy for distribution to the lamps and motors. To obtain the requisite electrical pressure, and avoid the use of magnets and armature of a weight and size which for mechanical and commercial reasons would be excessive, the engine is so constructed as to maintain a speed of 350 revolutions. A boiler pressure of 120 lbs., made absolutely safe by the use of approved sectional boilers, the high speed, and variable cut-off valve, and manner of constructing the engine makes this method of generating electricity absolutely safe and economical, and the uniformity obtained in regulation of speed insures a corresponding steadiness in the current and therefore in the lights which it supplies.

The following approximate summary of weights and dimensions of various parts of the latest "steam dynamo" constructed will give an idea of its total size and power.

Cast-iron sole plate, in one piece, upon which dynamo and engine are placed, and pillow blocks, 9,600 lbs.; Magnets, complete, 24,500 lbs.; Armature, complete, and shaft, 8,500 lbs.; Engine, 10,000 lbs. Total weight, 44,600 lbs.

The total weight of copper on armature and magnets is 3,600 lbs.

Principal dimensions: Sole plate $12\frac{1}{2} \times 8\frac{1}{2}$ ft.; length of magnets, 8 ft.; length of armature (commutator makes additional length of 9″) 5ft.; diameter of armature, 28″; Engine cylinder, 11″×16″; capacity, 2,400 gas jets.

GASEOUS FUEL.

From "The Building News."

WE have so long been accustomed to regard coal-gas merely as an illuminant, that it requires some effort to familiarise ourselves with the opinion which is daily gaining ground, that gas, suitably prepared and consumed in furnaces and stoves of proper construction, is among the best and cheapest kinds of fuel. One of the foremost and ablest advocates of the employment of gaseous fuel is Dr. Siemens, whose name is justly honored by all students of science as the inventor of the regenerative furnace, and the pioneer of the employment of electricity for illuminating purposes. Dr. Siemens has recently urged the preparation of two kinds of coal gas which he proposes should be distributed in separate mains, and be each of them specially adapted for the particular use to which it is to be applied. The gas given off from the retorts at the beginning and end of the process of gas-manufacture is far less rich in illuminating qualities than the gas expelled during the other part of the distillation, and the doctor has pointed out that by collecting the gases evolved at the commencement and close of the operation, and separating them from the remainder of the gas, it would be easy to obtain from, say, one ton of coal, one-third of illuminating-gas of high quality, or about 3,520 cubic feet, and two-thirds heating-gas, 7,040 c. ft. In London and many of our large towns it would scarcely be necessary to provide any additional mains, as, owing to competing companies, or the extension of the supply, many of the streets already contain a duplicate set of pipes. But even if it

became necessary to lay fresh mains, to make new house connections, and to provide a second meter to each house, the advantages of the plan proposed by Dr. Siemens would, we think, repay the additional outlay required. The cost of cheaper and less perfectly purified heating-gas might be kept as low, probably, as 1s per 1000 cu. feet, while the pure and high quality of the illuminating-gas might fairly enable it to be charged for at the rate of ,say,5s per 1,000 cu. ft. We need not, for the present argument, sup pose that the heating-gas would be distributed without any attempt at purification, for it would certainly pay the gas company to take from it certain impurities which now constitute a considerable source of revenue, and amply repay the cost of their extraction. We have reproduced the stock arguments of gas managers against the plan propounded by Dr. Siemens, in order to show that though at first sight it might appear that there are considerable difficulties in the way of such a scheme, they are by no means insurmountable, and could readily be overcome if needs be. The main obstable to any attempt at progress at the present time is the comparative insignificance of the demand for gas for any other purpose than that of lighting, and the strong position of the gas companies in the absence of any serious competition. We may assume that at the present time each ton of coal carbonized yields about 10,500 cubic feet of coal gas. This volume of gas, sold as at present for 3s. per thousand cubic feet will yield 31s. 6d. to the company. They have no inducements to split up this gas, even if a brisk demand arose for cheap heating gas, into, say, 3,500 cubic feet of 18-candle gas at 5s. per 1,000 feet, and 7,000 cubic feet of heating gas at 1s., for they would obtain only 24s. 6d. for the same volume of gas. Even if we take the best possible case, and assume that the total yield is broken up into 7,000 feet of 16.25-candle gas at, say, 4s.,=28s.; and 3,500 feet of heating gas at, say, 1s. = 3s. 6d.; total, 31s. 6d., the company only gain the same price as at present, and they have to undertake a double distribution. From the experiments of M. Ellisen, of Paris, it would appear that the latter case represents the most favorable results to be obtained by splitting the gas into two qualities. When half the total volume of each kind of gas is obtained, the lighting gas is of 16.78 candle power. It is worthy of notice that even the very high qualities of gas do not actually contain more than 6½ per cent. of illuminating constituents. In ordinary gas, such as that supplied in London, in each 100 cubic feet there are only four which actually yield light; the remaining 96 cubic feet are chiefly heating gases, which burn with a colorless flame. We do not wish to make out that the gas could be used without these heat-giving constituents; indeed, they have a most important office to perform in raising the temperature of the flame, in order to permit of the perfect combustion of the hydrocarbons. We only draw attention to this fact in order to show what a relatively large proportion the non-lightgiving gases bear to the illuminate—viz., about 24 to 1.

But when cooking and heating by gas and the employment of gaseous fuel for manufacturing purposes comes to be a little better understood, we very much doubt whether even the cheaper form of coal gas, prepared, as at present, and which we have assumed might be sold at 1s. per thousand cubic feet, will ever become the fuel of the future. Heating gas of very good quality, and in every way well adapted for domestic and manufacturing purposes, can be obtained at an infinitely less cost, and with a far cheaper description of plant than the gas which is distilled from coal in retorts. To this cheaper gas the term "water-gas" has been somewhat improperly applied, and such gaseous fuel as this can be prepared on a large scale at little more than 2d. per thousand cubic feet, with a fair margin of profit. Concerning the manufacture of water gas, we need say no more here than that there are numerous plans, all more or less efficacious, for decomposing water into its two gaseous elements, hydrogen and oxygen. By the best of the contrivances which are employed for this purpose, it becomes possible to effect the separation of these gases, and to cause the oxygen at the moment of its liberation to combine with a volume of carbon, producing the best form of gaseous fuel obtainable from coal—to wit, carbonic oxide gas. In the ingenious apparatus which has been

patented for the manufacture of this gas by the Dowson Economic Gas Company, water contained in a small boiler is converted into steam, and this steam is superheated in iron subes; a jet of the high temperature steam thus obtained is then passed into a furnace containing a deep layer of anthracite coal. The steam, acting on the principle of the injector, is made to carry with it an adequate supply of atmospheric air, and the red-hot coal at once decomposes it into its gaseous elements—a very copious evolution of gas suitable for heating purposes is thus effected—and the gas may be purified by passing it through a layer of spongy oxide of iron. The yield of gas is in the ratio of 1,000 cubic feet to each 12 lbs. of coal added to the furnace, and 180,000 cubic feet can be readily obtained from one ton of anthracite coal. This gas has a calorific power equal to about $\frac{1}{3}$ that of coal gas, so that, in round numbers, we may assume that each ton of coal will yield, by this treatment, an amount of gaseous fuel equivalent to that obtained from five tons of coal carbonised on the present system. But gas made by the decomposition of steam has no tar, no ammonia, and cannot possibly burn with a smoky flame; indeed, there can be no deposition of soot, even when a cold metallic surface is exposed to the flame. Moreover, the foul-smelling hydrocarbons which cause the disagreeable smell in ordinary coal gas, and which have led to many difficulties in using gas for cooking purposes, are entirely absent in the water gas. It will be quite possible for a few families living in adjacent houses to combine and to obtain a supply of this economic gas laid on to their houses in the same way as coal gas now is, and this new gas can then be employed in the kitchen, the laundry, the bathroom, and the conservatory, and the present use of coal as a fuel may be entirely abandoned. We are informed, indeed, that Lord Sudely has adopted the gas for all these purposes with complete success. We have still to mention that another important feature connected with this gas is the facility with which it may be carburetted or impregnated with illuminating constituents. This is assisted by passing it through a vessel charged with gasoline. The vapor of the gasoline is absorbed by the gas, which becomes thereby so much enriched as to yield a high standard illuminant, superior in fact to London gas. We should remember, in conclusion, the immense importance which the possession of such a gas implies when we require power for domestic or manufacturing purposes. In a gas engine of the "Otto" type, made by the Messrs. Crossley, this water gas can be used in the same way as coal gas now is, and the cost of each horse power is proportionately decreased. The actual cost of working, on an extended trial, with a $3\frac{1}{2}$ horse-power effective engine, has proved that one horse-power (indicated) perhour is obtained with a consumption of gas derived from 1-4lbs. of anthracite coal. When we contrast this result with the working of the largest and best steam engines, using 2 lbs. of steam, coal per horse power per hour, the gas engine has a large balance in its favor; but when we remember that with small steam-engines the common consumptiou of coal varies from 5lbs. to 6 lbs of coal per horse-power per hour, the advantage in favor of the gas engine and the new gas is too great to be long overlooked by those to whom cheap power is a desideratum.

DO STEEL SHIPS PAY?

"Nautical Magazine."

Mild steel has now been in use in shipbuilding a sufficient time to afford some material for a judgment as to its economical advantages as compared with iron. In a paper read before the Institution of Naval Architects in 1878, Mr. Martell estimated the saving in weight obtained by using steel instead of iron at 18 to 19 per cent., and his calculations as to the consequent gain were based upon that percentage. Lloyd's Registry allow a reduction in scantlings of 20 per cent., but it is obviously impossible to obtain the benefit of this in every case owing to the fact that both iron and steel are only rolled to certain sizes, plates, for instance, only graduating in thickness by exact sixteenths of an inch.

It appears certain that the actual saving of weight is much less than 18 per cent., but as to the exact amount of the ratio and whether it is sufficient to pay a good interest upon the increased cost, there is still room for much difference of opinion. Two valuable papers have been read upon the subject before scientific societies recently, one by Mr. Denny, of Glasgow, before the Iron and Steel Institute in May last, the other by Mr. Price. of Jarrow, at the autumn meeting of the Institution of Mechanical Engineers at Newcastle. Mr. Denny as a result of some few years experience in steel shipbuilding, is of opinion that steel ships are a profitable investment even at the present (which he believes to be but temporary) high price of steel; Mr. Price on the other hand, having gone into the question with a view to designing some steel ships, is so firmly convinced of their unprofitableness that he recommends all his clients to have iron vessels. It may be of some interest to our readers to have these two views of the question placed side by side with some of the facts and figures respectively adduced in their support.

Mr. Denny gives as the result of his experience in building steel ships, that the saving in weight varies from thirteen to fourteen per cent. only. He gives the figures for an iron spar-decked steamer of 4,000 tons gross, compared with those for a similar vessel built of steel. The iron purchased for the first amounts to 2,333 tons, the metal for the second is 2,030 tons, which gives a difference of just over 13 per cent. It may be remarked that there is less scope for the 20 per cent. reduction on scantlings in a spar-decked vessel than in a full three-decked vessel, for the reason that the scantlings are smaller, and for the same reason still less could be, as a rule, gained by building awning-decked vessels of steel. Of the 2,030 tons, there are required for deck houses, coal bunkers and other parts of the vessel which do not contribute to her structural strength, no less than 340 tons. In these no reduction is practicable; when made of iron they are as thin as is consistent with the necessary rigidity, and mild steel is less rigid than iron. Mr Denny also tells us that although mild steel has been used for forgings they have not seen their way to reduce the weight of these. It is thus the case that 381 tons of the metal are not subject to reduction at all. In the remaining 1,952 tons of iron, the reduction obtainable in practice is found to be 18½ per cent., but this reduction is in cubic contents only, and since mild steel is found to be 2½ per cent. heavier volume for volume than iron, the total weight of steel used in place of iron is 1,631 tons, which, with the indispensable iron upon which no reduction is practicable, gives the total weight of metal required for a screw steamer as stated at the outset. In this estimate the amount of metal paid for is taken; the actual weight in the ship is less than this by 9 per cent. in each case for waste scrap, and thus the increase in dead-weight capacity becomes 276 tons, that is, 7 per cent. upon the figures of the gross register tonnage. Mr. Denny states as the result of his experience that this rate is pretty nearly constant, that is, that the figures of the increased deadweight capacity obtained by using steel in place of iron in the same design may be obtained by taking 7 to 7½ per cent. of the gross register tonnage. The net cost of the iron in the iron steamer would be at the present rate £14,500, and in the steel steamer the total cost of metal would exceed this by £3,574. The extra dead-weight capacity of 276 tons is thus paid for in construction at the rate of £13 per ton.

The next step is to consider what the value of the extra capacity would be. Of course, this would vary with the voyage. Mr. Denny selects the Indian trade and estimates that the extra net gain would in two years nearly pay the extra cost of the steel steamer. "That this argument," he says, "is appreciated by the great steam companies is proved, in the case of the London and Calcutta trade, by the fact that all the latest orders of the Peninsular and Oriental Steam Navigation Company and the British India Company, the two leading lines of steamers upon that route, have been for steel vessels. At the present moment these companies are building between them nine steel steamers of over 4,000 tons gross."

We have not space to follow Mr. Denny in a comparison of an iron steamer with one built of steel of slightly smaller dimensions, but which, in conse-

quence of the smaller weight of the structure, is able on a less displacement to carry the same cargo. In this case a considerably larger sum is paid for the smaller vessel, but the gain is said to be a decrease of draught and a smaller taxable tonnage. We do not think, however, that the best comparison can be made in this way. If two vessels have exactly the same dimensions, their expenses of propulsion, &c., are the same, and in this case it is possible and easy to set off on the one side the extra prime cost and on the other the extra earning capability, both due merely to the substitution of one material for the other.

Mr. Price, of Jarrow, who may to some extent be taken to represent the practical experience of Tyne shipbuilding, comes to an entirely different conclusion from that of Mr. Denny. The figures given by him, however, did not represent the case of a steel vessel actually built, but only a comparison of the weight and cost of an existing recently finished iron steamer with what a vessel of the same dimensions would have been, if built of steel. The gross tonnage taken was 2,285, and on this Mr. Price calculated that a gain in dead-weight capacity of 118 tons would be purchased by an additional expenditure for the dearer material of £2,760, or at the rate of £23 8*s.* per ton. Mr Price thus concludes the comparison:—

"Now we may assume with perfect safety that the iron steamer, such as is described, could be built and equipped ready for sea, including all cost of engines, boilers, &c., for £10 per ton of dead-weight capacity. This would make her price for 3,235 tons dead-weight capacity to be £32,350. Add to this £2,760 for the extra cost if the vessel is built of steel, and we have £35,110 as the cost of the steel vessel for a dead-weight carrying capacity of 3,353 tons. This shows the average cost per ton of dead weight to have been increased from £10 to £10 9*s.* 6*d.*, or an increase in the entire cost of $4\frac{3}{4}$ per cent." This way of considering the question appears to us to be unfair as regards steel, for the reason that however the cost per ton of dead-weight capacity may be useful in comparing one iron ship with another, it is manifestly erroneous in comparing a steel with an iron ship of the same size. The working expenses of the two ships, including the coal consumption for a given speed, would, since they are of exactly the same design, be equal; hence the price per ton, at which the increase of dead weight is obtained by a saving in the weight of the structure, is paid for by so much clear gain in freight subject only to extra charge for insurance of the extra value.

Mr. Price also urges that in a steel ship it would be necessary to have a larger ballast tank because of her lighter structure, and this tank involves again additional expense, and its weight somewhat detracts from the former assumed saving of weight. There is, further, he says, the disadvantage that the measurement capacity of the hold is decreased by the increased size of the tank. It was very properly pointed out, by a speaker in the discussion upon the paper, that it would not really be necessary for the sake of proper stability, to immerse the steel ship when in ballast as deeply as the iron one. The decrease in weight proportionately is as much in her upper works as below, and an inconsiderable addition to the ballast tank would be all that was necessary to compensate for the slightly larger actual decrease in weight below over that in weight above the center of gravity.

In two vessels of extreme types, but of about the same size, the net cargo capacity may in one case be two or three times that of the other, hence an addition of so much cargo capacity free of all drawbacks, would in the latter case be worth two to three times as much as the former. In the sailing ship, or in the slow steamer running short voyages, the gain might not be worth the extra cost, while in the fast passenger ship, especially in the case of very long voyages, it would be worth many times the money paid for it.

The present price of steel plates and angles for shipbuilding is still more than 50 per cent. in excess of that of iron, and there appears no probability at present of much material decrease. One great reason for the difference in price is the severe testing to which the steel is subject. This is, however, as we have often urged in these pages, a necessary concomitant of the reduced scantlings; without it the extra quality in the material cannot be secured to compensate for the reduced size.

OUR PROGRESS IN MECHANICAL ENGINEERING.

THE PRESIDENT'S ANNUAL ADDRESS.

American Society of Mechanical Engineers, New York Meeting, November 3d, 1881.

By ROBERT H. THURSTON, President.

Gentlemen of the Society:

It is impossible, in the limited time that must be allotted to the President's annual address, to do more than glance rapidly over the broad field of mechanical engineering, selecting for study the more prominent and more important departments, and very briefly noting what is their present state, and how far improvement has progressed during late years. The direction of movement to-day becoming known, and the character of the difficulties presenting themselves being ascertained, the way in which accelerated progress may be rendered possible, becomes more easy of detection. In many cases we shall find ourselves able to decide precisely where to look for such progress, and, in all directions we shall find our exploration interesting, gratifying, and profitable. We will first examine those departments which supply us with our materials.

In that field to which we are apt to give too little consideration, notwithstanding the fact that it lies at the base of all our work, a field which—formerly cultivated by many of the greatest men that our profession has known—is now too generally neglected, while more seductive but less fruitful, and, on the whole, less immediately important departments are overcrowded with able workers, in that of the materials of construction, we are making steady progress on every side.

We are everywhere giving up the use of that expensive and perishable material, wood, and the weak and brittle minerals, and are substituting for them iron and steel.

Iron is slowly but steadily and inevitably being displaced by steel. Cast iron in small parts is less and less used as steel castings become more and more reliable, and especially as the art of making drop-forgings of larger size and in more intricate forms is perfected. Sheet steel, very low in carbon and other hardening elements, is becoming, year by year, more generally adopted in boiler-making, not because of its greater strength, for the stronger grades are always rejected by the experienced boiler-maker, but because of the greater uniformity, ease of working, freedom from cinder, and the durability of those grades which are well suited to such use.

A tenacity of *less* than 65,000 pounds per square inch (4,550 kilos. on the square centimeter) and great ductility are demanded for this work.

In rods and bars, and for sheets to be used where mechanical forces only are present, we are getting steel which, with a tenacity of 80,000 pounds per square inch (5,624 kilos. per square inch), stretch 25 per cent. before breaking, and we are sometimes given a grade very low in carbon, but high in manganese, which has ten per cent. higher tenacity and equal ductility. In fact, we are apparently coming to a *manganese steel* as the metal for use in general construction.

In making alloys I have been able to show the existence of an alloy of copper, zinc and tin of maximum possible strength and to point out approximately its composition, and my discovery has been confirmed by other investigators, who have independently hit upon alloys closely related to this "maximum metal," and possessing properties of hardly less value. We now know that by carefully proportioning the constituents, by proper fluxing the alloy, and by special mechanical treatment we may obtain brasses and bronzes having strengths undreamed of by earlier engineers. Tenacities of from 75,000 to over 100,000 pounds per square inch (5,273 to 7,030 kilos. per square centimeter) have already been attained.

The introduction of special alloys having extraordinary strength and uniformity of composition, as the phospor

bronzes, manganese bronzes, and sterro-metal, indicate that workers in metal are beginning to enter upon the path long since opened to them by scientific research.

Dr. Fleitman's discovery of a method of making nickel malleable, and capable of welding, and his similar improvement of commercial cobalt by the use of magnesium, is in itself important, and promises to lead the way to further progress.

In the application of the materials of construction we are learning some exceedingly important facts, the most valuable of which relate to those most "precious" of the metals, iron and steel.

The effect of variation of temperature in the annealing of these metals, and in the hardening and tempering of steel has long been known. That annealed and unannealled wire differ widely in tenacity and in ductility, that very "mild" steel and good iron are softened by the very process which gives hardness to steel, are long familiar facts, and it has probably been long known to many engineers that there exists a critical temperature, probably definite and fixed for each grade, at which the hardening of steel occurs. Passing this point in cooling the metal takes on its temper, but variations of temperature on either side that point produces no observable effect on its condition however rapidly they may take place. This critical temperature has now been identified in certain cases, and may prove to be nearly the same for all steels.

The process of "cold-rolling" has long been known to engineers as an exceedingly valuable method of enormously increasing the strength and elasticity of iron. We have now learned that it is applicable to the soft steels, and I think it will become certain ere long that its full effects may be obtained at any temperature below that critical point which defines the limit of molecular stability, as I have just stated it, in steel.

Lauth's process has been applied with equal success to certain alloys of copper and tin, by Sears, in the United States, and later by Rosetti, in Italy, and very extensively and successfully by Uchatius, in Austria. Tobin has cold-rolled bronzes, approaching the "maximum" alloy in composition, and has attained tenacities exceeding 100,000 pounds per inch (7,030 kgs. per square centimeter).

The radical distinction which is observable in the behavior of metals under stress, and which leads to their division into what I have proposed to call the iron class and the tin class—in the variation of the normal line of elastic limits by intermitted stress—is becoming generally known. Engineers are beginning to perceive that that exaltation of the normal elastic limit, which is observable in the former class, is probably a valuable quality, one the existence of which may prove to justify the use of smaller factors of safety than have hitherto been thought allowable; and this leads to less expense in stationary structures, and to the elimination, to some extent, of stresses due to the inertia of moving parts in machinery. The conclusion reached by many engineers, that moderate static loads may be sustained indefinitely by iron and steel are also to this extent sustained.

On the other hand we are led to the observance of more than usual caution in the use of metals of the tin class, including most of the brasses and bronzes, and to the use, in such cases, of higher factors of safety than are demanded in constructions of iron and steel.

Preliminary straining to secure an elevated initial elastic limit with relief of internal stress is likely to be of service in the applications of iron and steel, as *e.g.* by cold-rolling, by "frigo-tension" and "thermo-tension" and by wire-drawing, while it proves to be probably less effective with other metals.

The experiments made for the Prussian Government by Wöhler and Spangenberg during a period of fifteen years, and which have now been concluded eight years, are just becoming known to practising engineers, and Wöhler's law, Launhardt's and Weyrauch's analyses of results are found valuable checks upon usual methods of proportioning iron parts of structures. It is becoming known that not simply the load to be applied, but the frequency and the method of its application, and the condition of the structure as determined by earlier strains, must be considered in settling upon its dimensions, and upon the magnitude of the factor of safety.

Nevertheless, in ordinary work we find that, as experience has taught us, these quantities are well covered by the factors of safety that have become generally accepted. The great value of these researches, and of the many others of the same kind which have been made in every part of the civilized world, is found to come of the ability now conferred upon the engineer to proportion with confidence parts exposed to exceptionally great and unusually variable stresses.

Perhaps the most important advance made in the use of materials in engineering has been the general introduction of systematic inspection, and of careful test of all materials used. Such inspection and test is now demanded by every well-drawn specification, and is carried out usually by trained and skillful inspectors.

The Pennsylvania R.R. Co., the Bethlehem Iron Co. and other well-managed establishments have even organized complete departments devoted to the examination and test of all materials offered them, and often find that a single investigation repays the whole cost of the department for a period of years. So essential is that system found to be that I am frequently called upon to advise in regard to new "laboratories" in all parts of the country in which iron, steel, lubricating materials, and other supplies of value are to be systematically examined before purchase. This is not a mere matter of dollars and cents however. Every engineer who has experienced the anxiety which comes of uncertainty in regard to the character of the material of a structure, in which a single defective piece may cause the destruction of the whole with enormous loss of time, money, and, probably of life, will understand what good comes of a system of inspection and test that entirely relieves both conscience and pocket of responsibility and risk.

A method of inspection which, as I showed ten years ago, will safely determine the value of each piece, subsequently to be actually put into the structure or machine, is now slowly becoming adopted and we may hope that soon, we may confidently assert of each bridge over which we ride, of each machine upon the strength of which depends safety of life and property, that its every part has been proven, by actual test before use, to be perfectly safe. Now that the great testing machine at Watertown Arsenal, set up by the unfortunately defunct Board appointed in 1875 to test iron, steel and other metals, is at the service of the public, we may hope that such methods of test may hereafter become common, and that tests of full-sized parts of bridges and machines, made at private cost, may, to limited extent at least, yield the knowladge that that Board would have more systematically and at less expense have made familiar to engineers, had its life not been terminated at the very beginning of its labors.

I have to thank General Walker, the Superintendent of the Census, for many valuable data, and not the least interesting of all is the report of Mr. Swank, on the iron trades, of which I am supplied with an advance copy. I know of no better gauge of the extent and importance of the work of the mechanical engineer than the production of iron and steel. These metals are worked up by the mechanical engineer and the trades associated with the profession, and the consumption of the raw material is the truest measure of the magnitude and value of our work.

The growth of the iron manufactures of the United States have all occurred since A. D. 1700, when there was not a blast furnace in this country, and principally since the year 1794 when the first steam engine was erected in America, eighteen years after James Watt made the improvements that have given him fame, and that have given the world more wealth and comfort than had been accumulated during the many centuries of civilization historically known to us as preceding his time.

To-day, we have over 1,000 iron and steel works in the United States, employing \$230,000,000 in capital, as against \$122,000,000 in 1870-1871, producing 7¼ millions of tons of iron and steel, just double the production of 1870, and employing nearly 150,000 men. The value of all products is not far from \$300,000,000, and wages amount annually to about \$55,000,000. In ten years Massachusetts has increased her product 65 per cent., West Virginia, 104 per cent., Alabama, 800 per cent., nearly, Georgia, 125 and Tennessee 125 per cent.

Pennsylvania holds her place at the

head of the list, producing $3\frac{1}{2}$ millions of tons per annum; Ohio makes one million, New York, 600,000, Illinois, 400,000, New Jersey, a quarter of a million, and other states smaller amounts.

Since the year 1870, we have increased the weight of pig metal from 2 to $3\frac{3}{4}$ millions of tons per annum, or 84 per cent.; rolling mills make $2\frac{1}{2}$ millions of tons of rolled iron, an increase of two-thirds; the Bessemer steel manufacture has grown from less than 20,000 tons in 1870 to 900,000 tons in 1881; "open-hearth steel" is now reported at about 95,000 tons, and this is an industry which was unknown in this country in 1870. Of crucible steel, we make 70,000 tons—a gain of 150 per cent. in the decade—and its applications are extending wonderfully, day by day.

But Great Britain still remains at the head of iron-making countries, turning out 8 millions of tons of pig iron during the year, an increase of one-third since 1870, and the increase still continues. The weight of Bessemer rails made has reached above 700,000 tons, and of Siemens-Martin steel a quarter of a million tons per annum.

Germany and France exhibit similar gains in amount of iron and steel made, and other countries of the world follow after.

Even Italy, famous as the home of the fine arts, yet disgraced by her neglect of the useful arts—the country of beautiful art galleries and of uncomfortable homes—has produced about 300,000 tons of iron ore, of which a small amount is there worked into finished iron. The artistic sense of her people is even here seen, and her blacksmiths make architectural work in hammered iron which would have satisfied even Michael Angelo.

The introduction into open hearth steel making of the Pernot furnace with its revolving saucer-shaped hearth, and of the Ponsard furnace with its modernization of the ancient process, are the latest steps in the improvement of steel-making apparatus; and the dephosphorizing process of Thomas and Gilchrist, by permitting the use of hitherto condemned ores, will prove a grand step in the reduction of cost of Bessemer steel, which must hasten greatly that inevitable change which will, ere long, replace malleable iron by steel in all of its myriad uses. Good mild steel can at last be made cheaper than good iron, and we are now entering fairly into the "steel age."

This is the grandest of all the industrial revolutions that have affected the iron trades; although its influence upon the prosperity of the nation and of all civilized countries cannot be yet estimated, we may be sure that it will be hardly less observable, and that it will be of hardly inferior importance to the world, than was the introduction of puddled iron a century ago.

We are using steel in every department of our work, and that most remarkable of all its many grades, Whitworth's compressed metal, is now at last coming into commercial importance; and of it are to-day made shafts for the largest steamships and ordnance that has no equal in strength and endurance.

Any size desired can now be made in cast steel, and 100-ton ingots, shaped under 80-ton hammers, are the *pieces de resistance* of at least one European establishment.

The progress of art, directed by brain and sustained by energy, skill, and enterprise, is well illustrated by the changes which have taken place in our textile manufactures. According to Atkinson, a century ago one person in each family was compelled to work, day in and day out, nearly the whole year, to furnish homespun and dress goods for the rest; to-day, such has been the progress in the introduction of mechanism and automata, that one day's work in the year will, on the average, be sufficient to enable each worker to supply himself with all needed cotton and woolen fabrics.

Speeds of cotton spindles have risen, during the two decades that my memory can follow the change, from 5,000 to 7,500 revolutions per minute. Looms then making 120 picks per minute make now, Mr. Webber tells me, as high as 160, and one hand takes charge of from 25 to 50 per cent. more work. The "Slasher" dresser does *ten times* the work of the old machine, supplying 400 looms in place of 40, and demanding the attendance of only one man and a boy, instead of two men and ten girls. Pickers handle a ton of cotton per day in place of a half or five-eights ton.

The cheaply made turbine driving

these mills has completely displaced the old costly vertical wheel, doing the work with less water and greater steadiness.

Its efficiency has risen from 70 or 75 to 80 and 85, and sometimes to 90 per cent.

When the last generation was in its prime our factories were in operation twelve or thirteen hours; "Man's work was from sun to sun, and woman's work was never done." To-day man works ten hours, and woman is coming to a stage in which she will work where, when, and how she pleases. Then three yards an hour was the product for a single operative; to-day ten yards per worker are produced. In twenty years the annual product in cotton mills has risen from 2½ tons to 3½ tons per annum per mill-hand; wages have increased 20 per cent., and the buying power of the dollar has risen in much more than equal proportion, thus adding 50 per cent. to the comforts and luxuries of working people, permitting an increased number of happy marriages and comfortable homes, setting free the child-slaves of the mills, and turning them into the schools.

Where one hand then drove forty spindles, he now manages sixty; and every seven of the more than ten millions of spindles in operation works up a bale of cotton each year and turns out a hundred dollars worth of product. This product is supplied to the most indigent of our poor at a small advance on the one and a half cents for labor, and equal sum for raw cotton, which are expended in the manufacture of the cheapest grades. A still more striking fact is the distribution of our cotton goods to distant countries. A single mill operative at Fall River, Lowell, or Providence makes each year cotton cloth enough to supply 1,500 of the people who pay her wages by sending her tea.

In regard to woolen manufactures we have the same story to tell. All machinery has been speeded up, product increased, labor diminished, costs lessened, and machinery given greater automatism and higher efficiency both in making ordinary goods and in adaptation to finer grades. The manufacture has had a healthy growth, and the product is daily competing more successfully with the best of imported goods.

It is, I find, difficult, perhaps impossible, to make an exact statement of the extent of recent progress in the silk manufacture in this country.

Power looms and automatic machinery have been introduced more slowly in this trade than in others. Yet progress has been made. New and improved apparatus is steadily displacing older forms; power machinery is taking the place of hand-worked machines—with some rapidity in mills working the coarser grades, and more slowly where the finest goods are produced.

The strength, durability, and finish of all kinds of silks are constantly becoming more and more nearly equal to the best imported. Indeed, the ladies assure me that some makes of American silk wear much better than any of foreign make yet seen in our market, and that several grades have a finish which compares favorably with the very best of European silks. In variety and in quantity of goods produced a steady gain is to be noted. The ingenuity of the American workman, aided by talent and experience, coming from the older silk-making provinces of Europe, seem likely to give to this manufacture a position of which its promoters may well be proud.

Mr. Wyckoff, Secretary of the Association, reports, June 30th, of the current year a production in the United States of nearly $35,000,000 in finished goods, by about 400 factories, employing a capital of $19,000,000 and over 30,000 operatives, whose wages amount to about $9,000,000 per annum. Good progress this for an industry often condemned as exotic, and one which has only become established within the remembrance of the majority of our members. A half million spindles, running often 10,000 revolutions per minute instead of 5,000 as a few years ago, and over 5,000 power and 4,000 hand looms make a large showing. Spinning frames occupy $\frac{1}{40}$th the space, and cost $\frac{1}{20}$th as much per spindle as in the earlier days of the trade, and the cost of work has now become so small that $3.00 per pound spent in wages make silk costing $5.00 per pound into finished goods averaging $11.50.

In machine work generally the distinctively American idea of manufacturing as opposed to the old methods of making parts or mechanism in large numbers is steadily progressing, thanks

to the ingenuity of mechanics like our colleagues, Pratt and Whitney and others, in devising tools specially designed for the production of definitely limited kinds of work.

The same wonderful genius of invention which produced the Whitney cotton gin, the Blanchard lathe, our screw machinery, and the more wonderful card-setting machine has lately given us Sellers' automatic gear-cutter, the automatic turret-lathe, and a thousand and one machine tools hardly less remarkable in construction and efficiency.

Turning to the examination of the present condition of the railroad system of our country—that system which, binding State to State with lines of steel, is our strongest safeguard against political dissension and disunion—we find that changes are everywhere in progress under the direction of some of the ablest members of our profession.

It is now seventy years since Col. John Stevens, in his memorable correspondence with Dewitt Clinton, urged the adoption of a complete system of steam transportation on railways, and asserted that the time would come when "suits of carriages," as he said, would make their journeys, impelled by steam, with as much celerity in the darkest night as in the light of day, and stated that he "could see nothing to hinder a steam-carriage moving on its ways with a velocity of 100 miles an hour," and that he "should not be surprised" at seeing them propelled 40 or 50 miles an hour. His contemporary, Oliver Evans, wrote: "A carriage will start from Washington in the morning, the passengers will breakfast at Baltimore, dine in Philadelphia, and sleep in New York the same day."

But it was a generation later before these prophecies were credited; it was only when, fifty years ago, the introduction of railroads had an actual beginning.

To-day we have a hundred thousand miles of track laid down in the United States—we have about one-half of the constructed railroads of the world. Trains here and in Great Britain make 50 miles an hour on schedule time, taking water from the track, and receiving and delivering mails without stop. A speed of 100 miles—Stevens' maximum figure —has been many times attained. Locomotives are frequently built weighing 50 tons; 70 tons has been reached, and every builder of engines is ready to guarantee the performance of an engine to draw 2,000 tons 20 miles an hour on a level track. In coal consumption we have made some saving of late years. Three pounds of coal per hour and per horse-power is a usual power, and a consumption of 2.6 pounds (1.2 kgs.) of coal, and of 22½ pounds (10 kgs.) steam has been reported from recent locomotive tests.

The trapping of cinder and the reduction of intensity of combustion by extending grate area are late improvements. The time will come, and it should have come already, when the nuisance of flying dust and cinder will be unknown.

Comparative comfort has at last come to the weary traveler in our parlor and sleeping cars, and the greatest of all modern inventions in this department, the Westinghouse continuous brake and the Miller platform and coupler, have decreased the risks of journeying by rail to a merely infinitesimal quantity.

A train which, when at full speed, can be stopped within its own length is comparatively safe against the most serious of usual contingencies.

Steel rails have driven out iron, and this superior metal is slowly and surely taking the place of its defective rival in boiler and running parts. It is an interesting fact that, while Bessemer steel is used for rails, open-hearth steel is coming to be as exclusively used for all parts of the locomotive.

The efficiency of the late styles of stationary engines is illustrated by figures like these: Corliss obtains a duty, as reckoned from figures recorded by my assistant at a recent 12-hour trial of his last Providence pumping engine of 113,878,580, without reduction or allowances, and the average of several days trial is 112 millions. Leavitt gives me data showing a duty for months together of about 105 millions, and obtains a horse power with an expenditure of 16½ pounds of feed-water per hour at Lynn and 16.23 at Lawrence. His Calumet engine with wet steam and but 200 feet piston speed, demands but 18 pounds (8.2 kilos.), and the Hecla hoisting engine is credited with the wonderfully low figure—16 pounds (7.3 kilos.). This, by the way, is the more remarkable from the

fact that the jackets were disconnected. We thus sometimes meet with hints, apparently, that we may do better work with an underheated than with an overheated cylinder jacket. The performance of the West-side pumping engines at Chicago, giving a duty of nearly 100 millions with lower heads only jacketted is similarly significant.

This figure—16 pounds of steam per hour and per horse-power—may be put on record as the very best economy attained by our best engineers at the end of the decade 1870-1880. It is just double the weight which would be required in a perfect engine working steam of the same pressure at maximum efficiency. This leaves us still a fair margin for further advance in the construction of the engine. The steam boiler is at a standstill; there is but little margin for gain in economy, but a large gain in weight of steam supplied per pound of boiler may be expected when the tardily recognized advantage of forced circulation is secured.

Air and gas engines are here competing with stationary steam engines, and, so far as I can see, in no other field. The compressed air engine, the petroleum engine, and the gas engine are all just now coming forward. I have no figures that I can rely upon except for the gas engine, which sometimes consumes as little as 18 cubic feet of gas ($\frac{1}{2}$ cubic meters nearly), per hour per horse-power.

The solar motor proposed by Ericsson, the inevitably coming motor of some far-distant epoch, has, as yet, made no progress beyond the plans and experiments of the inventor.

I have nothing to report relative to either the development or the application of the theory of heat engines. The splendid labors of Rankine and the work of that most logical and classical, if less practical writer, Clausius, have so cleared the field that later investigators are driven into the exploration of minor departments of thermo-dynamics. The engineer is to-day seeking, with the aid of the physicist, to determine the facts and the laws governing the exchange of heat between the working fluid and its enclosing walls. This is for him to-day the greatest of the problems presented in this department.

The purely commercial aspects of steam-engine economy, familiar as they have long been to builders of expensive engines and to the more intelligent buyers have barely attracted the attention of engineers generally, and have, as yet, apparently been entirely overlooked by all having a scientific standing with, I think, the solitary exception of that greatest of modern scientific engineers, Rankine. A year ago, in debate, I called attention to the fact that economy in fuel was but one among the many items of expense incurred in the operation of steam machinery, and that it formed by no means the greatest part of such expense in certain cases. The inference at once follows that commercial economy, affected as it is by all these items, must be studied with reference, not to cost of fuel simply, but with a view to making total expense a minimum. Rankine called attention to this obvious conclusion many years ago, and a paper presented by two of our colleagues at the May meeting in Hartford, extending Rankine's work, and applying his approximately exact method to modern engines, showed that commercial efficiency is often made a maximum with very much smaller engines, and lower rates of expansion, than are found to give maximum economy of fuel. Such methods of determining size of engine will probably be generally adopted by engineers seeking the best interests of their clients. We are not, it is evident, to conclude, from the results of the application of the Rankine method of determining size of engine and maximum commercial efficiency, that we are always to lose so large a proportion of the gain obtainable by further expansion of steam. We conclude, rather, that the engineer must direct his attention to improvements designed to reduce these counteracting wastes. He must find methods of rendering the machine, including boiler, automatic, and thus of reducing cost of attendance; he must find ways of reducing first cost, as by increasing speed and making smaller engines do the work, as by finding ways of building cheaply, yet doing good work, and of making lubrication less costly, or of doing away with it altogether. Automatic firing, or "stoking," automatic feeds, and automatic cleaning apparatus are already in use, as well as automatic regulation of

the engine, of steam pressure, of point of cut-off, and of chimney draft. All these improvements, when once made successful and thoroughly reliable, will come in effectively to aid the engineer in this direction, as well as the more direct advances in progress in the direction of reducing back pressure and of checking cylinder condensation, of increasing steam pressure, superheating, and obtaining by the use of all known methods of high ratios of expansion at maximum efficiency. The engineer and the physicist working hand in hand in the future as they have in the past—or perhaps the engineer-physicist—will sooner or later, following the paths pointed out by Smeaton and Perkins, and in our time, by Corliss, Porter, and Leavitt, greatly reduce the now often broad margin between theoretical efficiency and commercial economy. When the engineer has once acquired the habit of gauging the value of an engine by the magnitude of its ratio of expansion at maximum efficiency, all this latter class of improvements will advance with increased rapidity, and when he sees that the magnitude of the ratio of expansion at maximum commercial economy is a gauge of his success in making steam power useful, the first class of improvements and of inventions will similarly advance, while we shall gladly approximate to mechanical perfection, and this progress will occur at a rate which will be measured by the approach of the two ratios of expansion to the same maximum, finally both becoming nearly coincident with the ratio of maximum efficiency of fluid for each given case.

The "compound" engine has become the standard type of steam engine in use on shipboard as well as for stationary pumping engines. We still hear occasionally intimations that a counter-revolution and return to the single cylinder type of engine may be expected, but that change is not observable. The direction and extent of recent advances in marine architecture are readily noted. The proportions of length of ship to breadth remain, as during several years past, about 10 to 1 or 11 to 1, about 50 per cent. greater than has been considered by some of the best engineers as that giving highest efficiency. The Great Eastern 680 feet long, of 83 feet beam, and measuring 25,000 tons displacement, still remains the largest ship yet built; but steamers are under construction for transatlantic lines 600 feet long, of over 50 feet beam, and fitted with engines of 10,000 indicated horse-power. A speed of twenty miles an hour in good weather throughout the voyage, making the distance from land to land in less than a week may be expected soon to become usual. Double hulls and transverse bulkheads will make these great vessels safe even against the shock of collision with an iceberg.

Steam pressure has gradually and steadily risen since the time of Watt, when seven pounds—½ atmosphere—was usual. To-day 6 atmospheres (75 pounds per square inch) is as usual, and 7 atmospheres (90 pounds) is often adopted. Such pressures have compelled the general introduction of the simplest form of steam boiler; the cylindrical tubular boiler with large flues beneath the tubes, in which the furnaces are formed. Strength of flues is obtained by the use of heavy plates, sometimes flanged at the girth seams. "Mild" steel is here slowly displacing iron.

I have had occasion to remark, that in ordinary practice increase of steam pressure with correspondingly increased expansion gives, roughly stated, a decreased steam consumption, about in the ratio of the square root of the pressure. This seems true in recent marine engineering; during the past ten years steam pressure has risen from 4½ to 6 atmospheres—50 to 75 pounds by gauge—and the consumption of fuel per hour and per horse-power has decreased from 2 to 1.8 pounds (0.9 to 0.8 kilograms). Incidentally the area of heating surface has decreased from 4½ to 4 square feet (0.4 to 0.37 square meter) per indicated horse power, that is to say remaining, as formerly, nearly 2 square feet per pound of coal burned per horse-power per hour (0.4 square inches per kilog.) where, as in some cases, pressures of 100 and 125 pounds are adopted (7 to 10 atmospheres, nearly), somewhat further gain may be expected.

Increased pressure has been accompanied by increased speed of piston—from 300 to 500 feet per minute (100 to 150 meters, nearly)—and both causes have combined to reduce greatly the size and weight of engines. Formerly 500

pounds (220 kilogs., nearly) per indicated horse-power was a common figure; to-day one-half that weight is often noted, and in special cases in which, as in torpedo boats, economy is not important, one-fifth, and even one-eighth those weights are said to have been reached.

Surface condensation is almost exclusively adopted, but the area of cooling surface is becoming less and less, and at the pressure soon likely to become general, the production of a vacuum may possibly cease to be desirable, as it is already known to be with unjacketed cylinders; and the non-condensing engine may yet displace the condensing engine at sea as it has on land, and on our western rivers where this comparison was earlier made, and where the evil effects of cylinder condensation were earlier perceived. A still for connecting exhaust and waste steam into feed water has already been used, and it must remain in use in all salt-water navigation.

Among the most interesting events of the years 1880–1881 have been the trials of the steam yachts "Anthracite" and "Leila." The first is a small vessel 86 feet long, 16 feet beam, and 9 feet draught ($27 \times 5 \times 2\frac{1}{4}$ meter, nearly), fitted with a three-cylinder compound engine, and carrying 300 pounds steam (20 atmospheres, nearly) and upward.

Trials in London show these engines to have required but 1.7 pounds of coal (0.8 kilog.) and 17.8 pounds (8 kilogs.) of steam per hour and per horse-power. Cylinder condensation amounted to 30 per cent. in the first cylinder, and of this nearly three-fourths was re-evaporated before discharge from the third cylinder.

The same engines tested in this country require 21.6 pounds (10 kilogs. nearly) of steam per hour and per horse-power, the cylinder condensation becoming over 50 per cent., of which four-fifths was re-evaporated before reaching the condenser, the difference being probably due to a variation in the efficiency of the steam jackets and in speed of engines. This little yacht—the smallest that ever crossed the Atlantic—should be remembered in history, quite as much on account of the lessons in engineering learned on board the little craft as, on account of her far famous voyage.

The trial of the "Leila," under the orders of the U. S. Navy Department was even more instructive than that of the "Anthracite." The "Leila" is a Herreshoff yacht 100 feet long, 12 feet beam ($30 \times 3\frac{1}{2}$ in., nearly), and measuring 37 tons. With a "coil" boiler, steam at 120 pounds at the steam chest (9 atmospheres), and driving the boat 15 knots an hour (17 miles), the engines developed 150 horse-power, using but 16.4 pounds of steam (7.5 kilogs.) per hour per horse-power. The cylinder condensation amounted to but 10 per cent.

An important deduction from the results of the trial of the "Anthracite" and the "Leila" is, that efficiency has little relation to size of engine when protection against cylinder condensation is secured, and this conclusion is further justified by the fact that some of the very best work has been done, where non-condensing engines have been compared, by small portable engines. Steam engines of five thousand horse-power are equaled in economy by engines of one-fiftieth that power. A large difference in magnitude seems more than compensated by a moderate difference in steam pressure. We may conclude that high steam pressure cannot be expected to give great economy unless employed intelligently. The highest pressure may prove least economical when the engineer neglects to provide against loss by cylinder condensation. In the cases of the "Anthracite" and "Leila," the higher pressure gave least efficiency. We may, perhaps, obtain some idea of the relative efficiencies that should have been attained in the following manner:

Assuming that the steam condensed and re-evaporated had one-fourth the value of that remaining, the work done per unit of weight of working steam becomes for the two cases nearly as $\frac{70+7\frac{1}{2}}{70}=1.11$ is to $\frac{90+2\frac{1}{2}}{90}=1.03$, and as 16 pounds of steam per hour and per horse-power is to 15.9—practically the same, although the steam pressure was twice as great in the first case as in the second. We are evidently finding it more and more necessary to discover some means of making the interior surfaces of our steam cylinders of non-conducting material. That accomplished, the cost of power, in

quantity of steam used, will be reduced from ten to fifty and more per cent., according to the kind of engine considered. Until that is done, superheating, steam-jacketing, and high speeds of piston must be relied upon to give high efficiency; but only perfectly adiabatic expansion can give maximum economy of steam.

The error, long since detected by engineers experienced in the management and familiar with the working of steam engines, which has been fallen into by writers of authority, who have assumed that the condensation of steam due to transmutation of heat into work, discovered by Rankine and Clausius, produces the principal part of the water observed in the cylinders of engines working dry steam, is becoming generally recognized, and later writers are in a fair way to learn that it is not the fact that "the greater part of the liquid water which collects in unjacketed cylinders" "is produced by liquefaction of steam during its expansion;" but that this latter amount is insignificant, and that this water comes of cylinder condensation, sometimes with considerable leakage, and often amounts to a half or more of all the fluid supplied by the boiler. This fact once well understood, it may be hoped that this defect, existing in all heat engines, may soon be remedied to such an extent as no longer to constitute the great obstacle to further advance. The working of a fluid, of which the efficiency depends upon adiabatic change of volume, within a vessel so perfectly pervious to heat as is an iron steam cylinder, from the physicists stand point, involves an absurdity.

The trials of steam engines, now often conducted by the Forey & Donkin method of measuring the heat rejected, afford a reliable means of measuring actual efficiences. Recently, Eckart has applied the chronoscope of Hipp to the determination of the exact velocities of piston in mid-stroke, and we may expect soon to know much more than we do at present of the precise action of steam in the engine, and of causes of variation in efficiency.

Naval engineering is one of the most interesting and important branches of our profession, and the progress which has been made in its field during our generation illustrates the advances observed in nearly every other department. Naval works, whether in the civil or the military—in the "merchant" or the distinctively so-called "naval"—marine is to-day become almost purely the work of the mechanical engineer. The shipbuilder constructs his ships of iron and steel; their lines are laid down by the laws of engineering science; their parts are formed in the machine shop and put together by the same methods that are adopted in constructing their boilers. They are driven by steam engines designed and built by our fellow engineers, and the winds no longer either aid to any great degree, or seriously impede, their progress. Even their loading and the discharge of their cargo have become minor matters of engineering. The old-fashioned mariner is rapidly disappearing and the engineer is likely to become the responsible officer on the voyage as during construction.

Progress, if not more rapid in the Navy than in the Army, is more observable, and to me, at least, and perhaps partly because of my personal knowledge and closer relations, more interesting in its connection with engineering. A generation ago, the French "Napoleon" line of battle ship, with her 100 guns and 600 horse-power engines, represented the most formidable of naval vessels. A little later — 1856 — our "Wabash class" of screw frigates, with their fewer, but much heavier, guns, were thought the type of the coming fleet; but it was then that the modern ironclad came to revolutionize all naval warfare.

Those greatest of engineers, Robert L. Stevens and John Ericsson, and the greatest of naval architects, Edwin J. Reed, have led the way to the construction of the war ship of to-day—a craft carrying ordnance weighing from 25 to 160 tons, at speeds varying from 12 to 16 knots; plated with from 14 to 30 inches of armor, and yet penetrable by their own guns—a great fighting machine, designed, constructed and mainly operated by engineers. The daily advance noticeable in naval construction is a progress leading directly and rapidly toward bringing all naval warfare within the province of mechanical engineering. The fighting sailor of

earlier days is giving place to the fighting engineer and mechanic upon whom success in handling these great fighting machines must inevitably depend. To-day, if two professions are to be combined, it is easier for the engineer to learn and to practice the duties of the sailor than for the seaman to make himself at home among the cranks and shafts, the rods and the valves of the engineer. In our own navy, the line officer is becoming a skilled engine-driver, and the engineer is studying in all the higher departments of his profession, both in naval and steam engineering.

But a revolution is impending that will produce, as yet, unknown changes.

Ten years ago, I proposed a classification of naval vessels which was a little later again proposed by J. Scott Russell in a modified form. I stated that the increase so rapidly taking place in weight of ordnance and armor must sooner or later compel the division of all navies into three classes of ships, and an independent service of torpedo vessels: (1) a class of vessels for service in time of peace, of moderate size and speed, carrying a few heavy guns, unarmored and with great sail power; (2) a class of unarmored ships of very high speed under steam and carrying a light battery, such ships as might be best calculated to destroy the commerce of an enemy; and, (3) a class for heavy fighting, carrying the heaviest of guns and the most impenetrable of armor, with as high steam power as possible, and rendered, by division into compartments, as nearly unsinkable as possible. A few years later, I stated that "the introduction of the stationary, the floating and the automatic classes of torpedoes and of torpedo vessels has now become accomplished, and this element, which it was predicted by Bushnell and by Fulton, three quarters of a century ago, would at some future time become important in warfare, is now well recognized by all nations. How far it may modify future naval establishments cannot yet be confidently stated, but it seems sufficiently evident that the attack, by any navy, of stationary defences, is now quite a thing of the past. It may be looked upon as exceedingly probable that torpedo ships of very high speed will yet drive all heavily-armored vessels from the ocean, and complete the parallel between the man-in-armor of the middle ages and the armored man-of-war of our times." These words are fully justified to-day; and the non-success of naval vessels in later wars, and the production of such craft as the Polyphemus, making 17 knots, and as Ericsson's Destroyer, with its great submarine gun, and the self propelling torpedo, guided from the shore, are simply very large straws, showing that the coming days of freedom on the high seas and of cessation of all naval warfare are not far away. This most splendid of revolutions is to be the work purely of the mechanical engineer. I have no doubt that many among my audience will live to see that forerunner of the millennium.

Gunnery is a branch of our profession which has been too much neglected by engineers; and progress, dependent upon laymen and upon a few of the military class, whose tastes rarely lead in the direction of construction, although, perhaps, much more rapid than should have been expected is much slower than may be anticipated, when this special department becomes the chosen field of educated, well-trained and talented mechanical engineers.

From the days of Tartaglia and of Rumford, the direction of movement has been readily traceable. Stronger and safer ordnance metal, breech loading in place of muzzle loading, increased velocity of projectile, a flatter trajectory with less lateral drift, and with enormously increased range are the features of changes now occurring. Whitworth's compressed steel, Krupp's breech mechanism and skillful design and construction have given us guns capable of driving shot at velocities of over 1,200 feet (over 360 meters) per second with small arms, and nearly 2,000 feet (600 meters) with heavy ordnance. Whitworth, with a comparatively small piece, has attained a range of nearly ten miles. The "machine guns" of Gardner, as built by Pratt and Whitney, and the Gatling and others, as constructed by the Colt Co. and the Ames Manufacturing Co., firing a thousand shots a minute, have rendered the old methods of warfare, in which large masses of troops were deployed in the open, entirely obsolete, while the accuracy of sharp-shooting at ranges of 1,000 yards or more make the use of any

unprotected ordnance at short ranges extremely difficult.

Hollow cast guns, as made by Rodman, although the best cast-iron ordnance ever known, are now of the past; and even the Armstrong, the Woolwich, and other guns built up in the forge, fail when made of 80 and 100 tons weight, as now demanded, and must inevitably, as I predicted several years ago, give place to solid steel guns of the Whitworth or other stronger type. Improved methods of making explosives and better adjustment to the work by variation of composition, and especially size and density of grain has enabled us to keep pressures much below 25 tons per square inch, while greatly increasing the energy developed per pound burned and correspondingly increasing the effectiveness of of ordnance.

The theoretical energy of good powder is about 250,000 or 300,000 foot pounds (80,000 to 90,000 kg. m. per kg., nearly) per pound. In experiments, every day in progress, we now get an actual result equal to two thirds.

This is is a branch of thermodynamics that must soon attract the attention of some scholarly engineer, familiar with practical work, and we may hope that so fruitful a field will not much longer be left so entirely uncultivated. There is, to-day, however, no difficulty in designing a gun to do any specified work, and but little in determining the resistance to be met and the energy demanded at a given range, or when attacking armor-plate. Fortunately, however, the days of iron-clads and of naval warfare will soon be numbered. Guns can be made to penetrate any thickness of armor that can be floated, and when the importance of a long bore, with slow burning or intermittently burned charges, becomes recognized, the effectiveness of ordnance against any armor will be such that the ironclad will soon vanish from the seas. There is still much to be done in perfecting ordnance, however, especially in its construction, and as yet our ordnance officers are completely at sea in respect to systems of construction of large guns. Treadwell and Woodbridge have pointed out one direction of progress by the application of the strongest known form of metal—hard drawn steel wire—in building up the barrel, and Whitworth has shown what wonders can be accomplished with steel in masses. Some of our fellow-engineers will undoubtedly go still further in this direction. The gun is already a heat engine of high efficiency, but thermodynamic investigations will show that this gas engine may be made still more efficient, and the chemist and the engineer will aid each other in perfecting it. A gun in which the charge expands 25 times should give to the shot an energy of 300,000 foot pounds per pound (90,000 kg. m., nearly) of good ordinary powder, and such a standard must sooner or later be closely approximated. As the heat is generated and expanded in a very small fraction of a second, the gas expands adiabatically, or insentropically, as Gibbs and Clausius would say, and the loss should be small except by incomplete expansion. It is sufficiently evident that we are yet to see the air chamber used intelligently, and, therefore, our guns lengthened greatly, and carefully proportioned to their work. It does not, even yet appear to have become understood that recoil is often simply an evil, and an avoidable one, with breech-loading guns; but the time must come, I think, when ordnance, whenever possible, if maximum battering power or range is required, will be held fast against recoil and thus the defect in efficiency, all the inconveniencies and some of the dangers now due to this waste of energy will be avoided. Recoil is, with modern ordnance, often an unmitigated and inexcusable evil. Increased accuracy and power with flattened trajectory and reduced drift will come with these improvements, and the last will give much greater convenience and safety in working, and will aid still more in the effort, which the engineer naturally makes, to unite guns and supporting structure as closely and firmly as possible.

That feature of recent progress in engineering which is to-day attracting most attention and awakening most interest in the minds of the public as well as of the profession, is the introduction of machine-made electricity, and of the electric light, but what seems to me the most important phase of this impending revolution is, I think, not yet generally comprehended. By the ingenuity and skill, the courage and the persistence, the energy and enterprize of our brother engineers,

Brush and Edison and their coadjutors, it seems certain that the dream of the great author of "The Coming Race" will in part be speedily realized, and that for the occasional mild light of the moon, or the yellow sickly flare of the gas flame, will soon be substituted the less uncertain and always available, and equally beau tiful and mellow, radiance of the electric flame. This is but a beginning, however. A few months ago one of the most earnest and best workers of all who have been with me—at once, friends and pupils—made a very painstaking investigation of the efficiency of a powerful dynamo-electric machine kindly loaned him from Menlo Park. The mean of several series of tests gave, as a result, an efficiency of between 90 and 95 per cent. That is to say: Of all the power transmitted to the machine from the steam engine driving it, over 90 per cent appeared on the wire in the form of electrical energy. It follows at once that mechanical power may be transmitted through two such machines, again appearing as mechanical power, with a loss of less than 20 per cent. And it follows from this last fact that the distribution of power by electricity is not unlikely to prove a more important application of this wonderful force than is the electric light.

It is to this inestimably important advance in that field in which the mechanical engineer and the electrician have joined hands, that we owe the probable early success of the electrical railway, that promising scheme of simplifying the problem of transportation on our elevated railways; and it is not unlikely that the rising generation may see the completely successful introduction of this method of distributing power from a central source in our great cities, and even from that mighty reservoir, Niagara, with its 3,000,000 horse-power to far distant cities on either side of this great Continent. Sir William Thompson has stated it as probable that 25,000 horse-power may be sent by this method from Niagara to New York, Philadelphia, or Boston through a half-inch copper wire, losing twenty per cent. in transmission; he would effect distribution by using the Faure battery as an accumulator. The competition of this method of distributing light, heat, and power with the already practical plan of steam distribution introduced by Holly, of Lockport, and now coming into use in New York City under the direction of Emery, will be watched with unusual interest.

I have sometimes said that the world is waiting for the appearance of three great inventors, yet unknown, for whom it has in store honors and emoluments far exceeding all ever yet accorded to any one of their predecessors.

The first is the man who is to show how, by the consumption of coal, we may directly produce electricity and thus, perhaps, evade that now inevitable and enormous loss that comes of the utilization of energy in all heat engines driven by substances of variable volume. Our electrical engineers have this great step still to take, and are apparently not likely soon to gain the prize that will yet reward some genius yet to be born.

The second of these greatest of inventors is he who will teach us the source of the beautiful soft-beaming light of the firefly and the glow-worm, and will show us how to produce this singular illuminant, and to apply it with success practically and commercially. This wonderful light, free from heat and from consequent loss of energy, is nature's substitute for the crude and extravagantly wasteful lights of which we have, through so many years, been foolishly boasting. The dynamo-electrical engineer has nearly solved this problem. Let us hope that it may be soon fully solved, and by one of those among our own colleagues who are now so earnestly working in this field, and that we may all live to see him steal the glow-worm's light, and to see the approaching days of Vril predicted so long ago by Lord Lytton.

The third great genius is the man who is to fulfill Darwin's prophecy, closing the stanza:

> Soon shall thy arm, unconquered steam, afar
> Drag the slow barge or drive the rapid car,
> Or, on wide-waving wings expanded bear
> The flying chariot through the fields of air.

The quotation may excite a smile to-day, but when first published, just one hundred years ago, the last lines must have seemed hardly more extravagant than the first.

And it is to-day true that we are getting on, that even in the science of aeronautics progress, although slow, is still to be observed year by year, and

there is no department of engineering in which the art of the mechanic has opportunity for greater achievement. We have not yet learned to fly like Daedalus, and thus have escaped the fate of Icarus, but the flying automata of Archytas, and of Regiomontanus have been matched in our own times, and the navigation of the air is, very possibly, on the point of real advancement.

When it is considered that it is only 98 years, last June, since the Brothers Montgolfier invented the balloon inflated with hot air, and that two months later M. Charles made use of hydrogen for inflation, it will, I am sure, be admitted that the progress which I am about briefly to sketch is far from being discreditable. Since Chas. Green, the famous English aeronaut, just sixty years ago, substituted coal gas for hydrogen, the progress of ballooning has been rapid, and science is greatly indebted to Biot and Gay Lussac, to Flammarian, to De Foroville, and especially to Glaisher, among balloonists, although, as yet little direct advantage has come to mankind from their efforts. The practical application of the balloon has been confined almost exclusively to the purposes of military reconnoissance. During the Franco-German war the great French naval engineer, M. Dupuy de Lôme, succeeded in giving to the balloon a slow motion by means of a screw, and in directing its course by a rudder. His balloon was spindle or cigar-shaped, and contained 12,000 cubic feet of gas. It could carry 14 men, and the screw was worked by four or eight men. But while it could be moved slowly in calm weather, this machine gave no encouragement to hope that self-impelling balloons will ever become successful. To support the weight of machinery they must have great bulk, and with great bulk no machinery yet devised is light enough, yet strong enough, to drive them at any such speed as is necessary for navigation in even a moderate breeze. Our only hope lies in the direction of flying machines, lifted by their own power, not buoyed up by gas.

And this scheme cannot hastily be condemned, nor by any means at once decried as chimerical, although, to-day, there is but little accomplished by man in this direction. The carrier pigeon and the wild goose are but animated flying-machines, and it can hardly be pronounced impossible that man shall yet compete with them in their own element, as he has long since learned to excel the fishes in their element. And a little has actually been done. Men of science like Pettigrew, Marey, and De Lucy have studied the motions of the wings of birds and insects, have learned the laws of fluid resistance, and have paved the way to a real advance. The theory of propulsion has been long studied and in some directions well established. It has been shown that weight is probably not objectionable in aerial navigation, but actually a necessity; not weight but volume constitutes the impediment. A bird is a heavy but compact structure, of which the essential characteristic is that it incloses great power within small volume. De Lucy's measurements of various flying creatures show an irregular, but still unmistakable, general direction of variation of wing surface with size of animal. Comparing the lady-bird and the stag-beetle, the pigeon and the stork, the sparrow and the crane, we find the area of wing per unit of weight carried to be nearly as the cube root of their weights. Taking as a fair figure that obtained from the larger bird, I find that a man of the ordinary weight should be able to fly with wings having an area of only about 40 square feet (nearly 4 sq. m.). De Villeneauve states that a bat having the weight of a man would need wings only ten feet (3 meters nearly) long. Hastings makes the surface of each wing from 5 to 10 times $\sqrt[\frac{2}{3}]{W}$ where the area is measured in square centimeters and the weight in grammes. Marey has made birds in harness record graphically the motions of their own wings, and Haughton and Marey and others have determined the working power of muscles in proportion to weight and size, and the method of movement of muscles and wing.

Henson, Stringfellow, May and others have made self-impelling model flying-machines, some of which have actually lifted themselves in the air, and several of which have flown with great speed when once lifted clear of the ground. But the most remarkable achievement of all, perhaps, is that of Henson in making a steam engine, fragile to be sure, but still a working machine, producing a third

of a horse power, and weighing *less than 15 pounds* (6½ kilogs). This machine was certainly more powerful than any bird of its weight could be. It is here that we seem most likely to be held in check, and it must be confessed that there is as yet but little on which to base an expectation of finding a satisfactory yet powerful motor.

Thus we are apparently approaching, though still, perhaps, far from, this goal, and we may barely venture to hope that the engineer who is to combine the elements of success, all of which are becoming determined, will in our own day win the fame that awaits the first successful builder of a flying-machine.

But all the efforts during this most wonderful of centuries just passing, of either men of science, or of engineers, would have been of little avail in the world, would have been unfruitful, however intelligent and however energetic the workers, without that other mighty power which preserves all science and sustains all art, which perpetuates both the fame of the inventor and the knowledge of his inventions. The art of printing, originating in an unknown past, dating its first grand expansion from the time of Guttenburg, and the use of moveable types, four centuries ago, has seen its grandest development during this last half century.

The introduction of the power press and the gradual incorporation into one automatic machine of the web-perfecting press of Sir Rowland Hill and of Jephtha Wilkinson's, of Worms' cylindrical stereotype plates, of Richard Hoe's type-cylinder and double-acting fly-frame; of Applegarth's enlarged impression-cylinder, and of minor improvements have led to the creation of the modern press.

To-day a daily paper can be printed at the rate of 30,000 impressions an hour, each paper printed on both sides, cut from the great roll—hundreds of yards long—in which it came to the press, pasted in shape and folded exactly to size, and then counted off by the machine as delivered to the carrier. The work of the compositor is soon likely to be wonderfully accelerated by the type-setting machine, which has attained, to-day, most extraordinary perfection. Paige's machine receives a column of "dead matter" from the press, distributes it automatically, sets it up anew at the rate of 3,500 "ems" per hour, including setting, justifying, and distributing—five times the work of the unaided hand. Its type last longer than when set by hand, and every defective or turned type is thrown out by this mechanical automaton.

Of all the observable signs of progress that attract our attention in these stirring times none are more interesting, and none more vitally important, than those which indicate the progress of this nation and of the world in the means and the methods of preparing the coming generation for its work.

The accumulation of wealth depends upon our material progress, and constitutes the only means of securing a steady progression in civilization, of conferring upon the world the blessings of intellectual and moral advancement, and of comfort and healthful luxury. But the accumulation of wealth means, not the piling of gold and silver in treasury vaults, and not the aggregation of fictitious values in Wall street, but the production of real property in buildings, in enriched lands, in mill machinery, in means of transportation, and in every form of durable material essential to the creature comforts of mankind.

The accumulation of real property depends largely, if not almost entirely, upon two great social conditions—the cheapening of food and other destructible necessaries of human life by the introduction of labor-saving mechanisms and processes and the steady and skillful application of the intellect and of the manual skill thus set at liberty, to the production of that form of permanent wealth, the accumulation of which during the past century has given to the working man of to-day comforts and luxuries unknown to kings and princes on the day of the birth of our country.

Now, all that can be done in this direction must be done principally by the mechanic and the engineer, and our immediate duty is to see to it that our children and our children's children shall have every opportunity to acquire that knowledge and that intellectual power, and to gain those means and powers of directing the forces of nature as well as to utilize their own natural strength and skill, and thus to do this work when the opportunity comes to them, with highest

success and most thorough efficiency. It is in providing the opportunity demanded by every good citizen to make his sons and his daughters capable of doing the work so coming to them, that the highest duties of the State remain to be fulfilled, and here it is that the signs of the times are most cheering.

When every man and woman, every boy and girl in the land is guaranteed the privilege of learning any business, and of engaging in any occupation that he or she chooses, or that circumstances may render advisable, and whenever and wherever it may seem best, a long step in advance will have been taken.

But the individual must be taught, not simply *permitted* to learn as best he can. Education, directed effectively with the object of giving, in least time and at least cost, a preparation for all the duties coming to the learner, whether in daily toil or in social life, is called for; trade schools must be incorporated into the common school system, and technical and professional colleges and great *Universities of Science and Art* must be placed beside the older academies of learning. And this need is most felt by our own colleagues, and by the people employed by them. He who would accomplish most in the profession of the mechanical engineer, or in the trades, must best combine scientific attainments—and especially experimental knowledge—with mechanical taste and ability, and with a good judgment ripened by large experience. He must be carefully, thoroughly and skillfully taught the principles of his art in the technical school, and the practice of his profession in office or workshop.

We have been late in seeing this necessity, and must suffer for our dullness as a nation; but we are beginning to open our eyes and to move in this most vital of all the duties of citizenship. One and two and three centuries ago, wise men like Pascal and Worcester and Vaucanson saw this greatest, highest duty of governments and citizenship, but it is only recently that we, as a people, have come to see its importance.

But now, the magnificent trade and technical school system of Germany, the older if less complete educational system of France, the tardily begun but splendid later work of Great Britain, and the grand beginnings made in the United States form a glorious commencement of a revolution that shall peacefully effect such changes during the next generation as, probably, no one can realize until after their actual accomplishment.

With trade schools in every town, techical schools in every city, colleges of science and the arts in every State, and with a great technical university as a center for the whole system, we shall yet see all combined in a social organization that shall insure to every one absolute freedom to learn and to labor in any department of industry, with absolute certainty of a fitting recompense for all the zeal, intelligence and good work that the worker, whether man or woman, may offer the world. Then, and then only, will the memory of those greatest benefactors of their race, Case and Hoe, Vasser and Durant, Rensselaer and Rose, Stevens and Packer, Pardee and Washburn be generally revered as we to-day revere them.

Then, and then only, will our profession attain its noblest development, and its science and its art, in closest union, aid most gloriously in the great work of emancipating mankind from the trammels of this animal nature, and of relieving the race from the pressure now felt in the terrible struggle for the necessities of life, substituting arms of iron and fingers of steel for these weak members of flesh to do the work of the world, leaving every human being having brains the opportunity to acquire knowledge, to enjoy life, liberty and the pursuit of happiness and to prepare for the future, as the knowledge, judgment and faith of the individual may dictate.

THE authorities of the Paris Mint propose to substitute for the present bronze piece, now almost as familiar in England as in France, a new coinage of a smaller and more elegant kind containing 20 per cent. of nickel. Specimen coins have been struck of the respective values of about a half penny (5 centimes), a penny, and twopence-halfpenny. The die used is the old one cut in the troublous time of 1793. Its device is an allegorical head of the Repuolic wearing a cap of liberty. It will be well for the Royal Mint to adopt a similar plan so far as the metal is concerned, for the bronze coinage of this country, as it is, is simply disgraceful.

THE DYNAMOMETER BALANCE.

Translated from "L'Electricien."

The exact measure of work has at present an important bearing upon the problem of the transmission of force to a distance by electricity. This operation is not without its difficulties, even when approximate results only are desired, and these are increased when the question applies to motors of feeble power or motors of high velocity, as is the case with dynamo-electric machines.

We sometimes require to know the total work absorbed by a machine generating a current, sometimes the available work produced by an electric motor. Here there are two quite distinct kinds of apparatus; those which measure the work expended are called "transmission dynamometers." The optical dynamometer of M. Latchinoff is of this class. (See Van Nostrand's Magazine for June last). Those which serve to measure the work produced belong to the same class as the Prony friction brake. It is well known that the method of this latter device consists in expending the work of the motor in producing friction, and then in measuring the value of the work of this friction.

M. Carpentier has improved the Prony brake in such a way as to apply it to the measure of the work of the little motors of M. Deprez. When the work to be measured is only a few kilogrammeters, it is always difficult to clamp the jaws of the brake with just the degree of force necessary to hold the lever arm in equilibrium, and all variations of the friction influence the results to an important extent. In order to obviate this inconvenience, M. Carpentier has devised an automatic clasp founded on the law governing the friction of a cord wrapped around a cylinder; a law according to which the friction increases much more rapidly than the arc of contact, and is practically illustrated in the belaying of a hawser to hold a ship.

The apparatus of M. Carpentier consists of two pulleys mounted upon the shaft of the motor to be tested. The first, A, is made fast to the shaft; the other, B, is a loose pulley.

Two cords are attached to B, which carry each a known weight at the extremity. The cord carrying the lesser weight, p, lies freely in the groove of the loose pulley. The other cord, also fastened to the loose pulley, is allowed to rest on the fast pulley, and sustains the weight P. Now, turning the machine in the direction in which the weight P acts, the cord which carries this weight produces friction on the running pulley A, and the difference of tension at the two extremities of the arc embraced by the cord increases very rapidly as this arc augments. The loose pulley tends to turn under the influence of the tension of this cord, but is restrained by the weight p acting on the other cord. The equilibrium is established automatically, and occurs at the instant when the tension of the cord carrying P (which varies with the arc over which it laps) is equal to the weight p.

If the pulleys have the same diameter the value of the work per second is given by the formula:

$$T=\frac{\pi dn}{60}(P-p);$$

in which

T is the work per second in the kilogrammeters;

d is the diameter of the pulleys in meters;

n the number of turns per minute;

P and p are the weights in kilogrammes.

Cords are conveniently used for motors of light power only. For heavier work M. Carpentier uses steel bands.

This plan is open to grave objections when applied to precise measurement. The frictional resistances, which are relatively large compared with the weights P and p being applied at the end of the shaft, tend to falsify the results to an extent inversely proportioned to the size of the motor, because the size of the arbors of small engines is relatively much greater than that of large ones. Furthermore, the weights P and p are not constant, by reason of the inverse wrapping of the

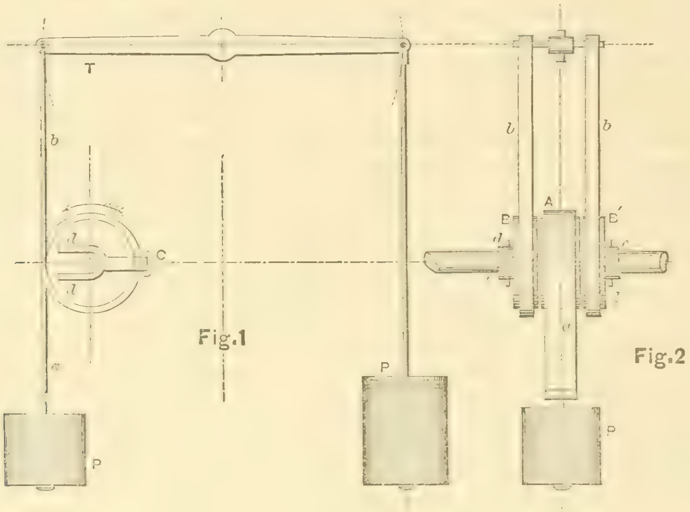
cords, but the error from this cause is of slight importance. The point of attachment of the cord that slides on the fixed pulley is not in the same plane as that of the loose pulley, which leads to an oblique pressure tending to unequal and rapid wear of the pulley and shaft, so that only narrow pulleys and bands can be employed.

In seeking to avoid these inconveniences, M. Raffard has constructed a dynamometric balance founded on the same principle as Carpentier's improved brake, but more useful practically, and capable of being applied to very feeble motors, or to engines of ten horse power, according to the size of the apparatus.

The lower side of the pulleys is allowed to dip into a shallow trough containing water or a solution of soap, for the purpose of lubricating the bands.

The size of the pulleys is regulated so as to present a circumference of a round number of centimeters, 20, 50, or 100. Knowing the value of $P-p$, and the number of revolutions per minute, the work is calculated by a simple multiplication.

The dynamometer balance is a complete apparatus; quite compact, and can be adapted in a few minutes to any machine by aid of a Cardan joint fixed to each end of the arbor of the brake.



M. Raffard's brake is shown in the figure. It consists of a pulley A keyed fast to a shaft, and two loose pulleys, B and B'. T is a lever to which the weights are suspended. C is a stirrup to which are attached the bands *a* and *b*. The weight of the stirrup is balanced by counterweights upon the arms *d*.

The principle of action is identical with that of Carpentier's brake. The weight P, acting by means of the lever upwards upon the pulley, relieves it of some of the pressure upon the bearings. There is no oblique action since the pressures act in the planes of the pulleys, and since the bands are not permanently fixed to the pulleys, the latter are not subjected to a constant wear upon one side only.

At the electrical exposition this brake is applied in the pavilion of the Societè la Force et la Lumière to measure the work produced by a Siemens machine driven by a Faure battery. Such measurements with a dynamometer so practical as Raffard's will serve to determine the true value of the so-called accumulators.

We shall also be able by the same means to determine the variation in efficiency of the dynamo-electric machines when the velocity and the current intensity are variable, for the real efficiency of these motors is nothing more than the relation between the electric energy furnished them and the effective work measured by the brake.

THE MANUFACTURE OF RUSSIAN SHEET IRON.

From "The Engineer."

So many different versons were current as to the process adopted for producing the sheet iron, known as Siberian, polished and unpolished, I determined when in the Ural to remain, if possible, at some one or more of the works, and watch the production from the ore to the finished sheets.

The manager, Ivan Ivanovitch Wohlsted, of the celebrated Demidoff works, obligingly offered me every facility, and in the report which follows the method followed there is explained; where from observation in other works, any difference of procedure of a serious nature was noted, I marked it, but the general conclusion I came to is that the manufacture of sheet iron is carried on with great care, great labor and expense, and that having good ore to commence with, the result is not difficult to obtain.

From the commencement to the end of the manufacture of the sheets I saw completed, I did not lose sight of the same, except they were under care; so that, as the manager said, there might be no uncertainty or quibble. The ore from which the metal is made is obtained close to the blast furnaces of the celebrated Tagil works, from which the C C N D bars are produced. This ore is very rich, and under arrangements is also used in other works, such as Takovleff, &c., the family of the original owner, Mr. Demidoff, of that district, having by marriage and sales given over right to others to mine there. The ore scarcely contains a trace of phosphorus, and not any trace of sulphur. The analysis is as follows:

$Si\,O^2$	7.871.
$Al^2\,O^3$	3.572.
$Fe^2\,O^3$	80.047.
Mn	—
$Mn^3\,O^4$	0.571.
Ca O	0.97.
S	—
Ph	0.25.

The flux used is ordinary limestone, found on the spot. Before being placed in the furnace the ore is roasted in heaps of from 10,000 to 15,000 tons, with charcoal made from *white* pine. If the iron is for sheets the workmen will not use charcoal made from *birch* wood. The roasting is done close at hand, quite in the open, and at any time of the year, the intense frost or heat not making any difference. In some works they prefer to roast the ore in the winter, and say *red* pine charcoal is not worse than white pine. The workmen assert that if charcoal made from birch wood is used, particularly in the blast furnace, then white specks are seen on the sheets. The managers say this is prejudice. The blast furnaces are oval. The size adopted as a standard has a capacity of 9000 cubic feet; the oval is 20 feet by 10 feet, being 52 feet high. The bottom is 3 feet diameter, and at 9 feet from bottom is full size of the oval. The system is Roshett's, with six tuyeres on each side, using hot blast at 200° Celsius. The furnace is charged every half hour with a thin layer of roasted ore and charcoal ore, broken up small and mixed with the flux; pieces of ore larger than a good sized walnut are not passed. The blast for three such furnaces is provided by three horizontal engines, each having a 29-inch steam cylinder and 5 feet stroke. The production is from 1500 lbs. to 2000 lbs. per day, 25 to 30 tons. New charcoal produces more than old, but the production varies little. The pig iron produced is at once puddled in an ordinary puddling furnace. The workmen attach importance to its being at once puddled, and make it into blooms of 100 lbs. to 200 lbs. weight. The puddling may be done with gas; it seems not to matter. Great care is taken to hammer the blooms well, to get rid of all impurities, under either a steam hammer or tilt hammer. Many workmen contend that the steam hammer is not so good as the tilt, but it seems simply prejudice. The blooms are at once reduced in a regular way into bars 5 inches wide, but of various thicknesses. After the bar has got rather cool the workmen stop rolling. These bars are at once cut into pieces 29½ inches and 30½ inches long, each

piece representing a future sheet, and being of various thicknesses for sheets of diverse weights.

Sheet iron in Russia is invariably made 4 feet 8 inches by 2 feet 4 inches (2 arshines long 1 arshine wide), and called 7 lbs., 8 lbs., 12 lbs., or 15 lbs. being made of all weights from 6 lbs. to 20 lbs. per sheet. Hence the thickness of the puddled bars is not much considered.

The puddled bars when broken show a fine granular fracture, somewhat steely, little if any fiber being found in the bars. About sixty of these pieces are taken—$29\frac{1}{2}$ inches for ordinary sheets and $30\frac{1}{2}$ inches for polished or "glanced" sheets—and put into an ordinary furnace heated with wood from below, the bars being placed on ridges in the upper chamber, the flame impinging through three openings on either side. The rolling down of these bars into sheets is a matter of three processes. First, each slab is rolled out into a plate as near as possible—workmen being guided by the eye—2 feet 6 inches by 2 feet 8 inches. Six men are engaged in this process. One man screws down the rolls to a fixed standard of thickness. There are two rollers, one man draws the slabs, and the other carries to the rolls. Whilst these are rolling the slabs down a sorter selects them in lots of three, putting a smaller one between two larger ones, and they are thus in lots of three returned to the furnace. Secondly, these "threes" are not tied together in any way, but simply assorted. Again at a fair heat are drawn out and brought to the rolls, held open by the roller, and a boy throws between the plates prepared powdered charcoal; the bundles are then passed through the rolls, the rolls being screwed down to the same point as before, the thickness of the three being reduced to the same as each was previously. Now the sorter again divides the sheets into lots by thickness, and makes bundles—not tied bundles—of three of the thicker, four of medium, five of thinner, and returns them to the same furnace. Thirdly, when the bundle is again at a good heat—red cherry—these lots of plates are brought to the rolls, opened out, and charcoal again powdered all over them, and the lots are passed through the rolls, until the thickness of the lot is brought to the standard of the original one slab. The sheets are now all sheared to one length—5 feet; in the width they are not touched. The sheets are now ready for the finishing process. Before proceeding to this, let me describe the preparation of the charcoal, a matter to which the workmen attach much importance, but which the managers do not seem to consider of any moment.

The workmen object to birch-wood charcoal, and prefer yellow pine and large-sized charcoal. It is first carefully washed to get out all earthy matter, ground in a mortar mill, or pounded under a hammer, washed again and dried, again pounded and sifted through a fine sieve. The workmen attach the greatest importance to using charcoal; but I saw sheets prepared without—which seemed quite as good, but the workmen contend that the sheets without charcoal soon lose the "bloom," or fresh look, especially with unpolished sheets. The sheets from the third process are stacked to cool completely—the lots I had in hand were allowed to stand in a rack from evening to morning—and are then assorted, as near as possible by the eye, into sheets of equal weight; seventy or eighty being considered a "pair" or lot for the future processes. Each sheet, being examined and brushed, is then dipped into a tank of water—the tank is never cleaned out, but kept full—"older the water the better"—and kept at about blood heat. Taken out of the bath, each plate is powdered all over with the prepared charcoal, dusted from or through a coarse linen bag. If the powdering is not done "equally" the color of the sheets will not be equal. The sheets being thus prepared, on the top and bottom of the bundle are placed two or three old plates to protect the sheets. The bundles of sheets being placed in the furnace are very gradually heated—the workmen considering that the more smoke there is in the heating of the bundles the better the sheets will be; but to get the bundles to a bright red heat, not less than seven or eight hours should be employed. The bundles I had in hand were dipped, powdered and prepared by 3 o'clock, and were in the furnace till 10.20—the same furnace as before described, but that on and around the bundle, wood was placed to prevent direct action of

the flames and produce smoke. When the packet was removed from the furnace, at a bright red heat, it was laid on a large iron slab, and every sheet was turned over, brushed with a wet fir broom, and when the bundle had got to a dark red it was placed under a wrought iron tilt hammer, and received in four minutes 200 to 210 blows—the hammer weighing 45 poods (15 cwt.); after this hammering every sheet was again examined on both sides, any dirt specks removed; particular attention paid to there having been no welding.

The bundle was again made up as before, put back again into the furnace to be again re-heated—this took 50 minutes. It was then again examined; again put under the hammer at a dark red and hammered for 14 minutes, receiving 750 blows. This was repeated a third, fourth, fifth and sixth time in following sequence:

	Packed in furnace.	Under hammer.	Number of blows.
	hours min.	min.	
First as noted.	7 30	4	200
Second time...	0 50	14½	750
Third time....	0 30	15½	775
Fourth time...	0 24	11	550
Fifth time....	0 30	7	350
Sixth time....	0 30	7	350
Totals......	8 34	59	2975

The bundle of sheets being examined by the hammerman, is handed over to the finishers, generally between 2500 and 3500 blows having been given. The first thing for the finisher to do is to examine each and every sheet. A ⅜-inch or ¼-inch plate is put on the slab, and each sheet examined; between each of the hot sheets is placed a sheet of finished iron—or two if the bundler thinks best—so that the packet becomes a bundle of from 200 to 220 sheets. It is at once taken without any reheating, and the bundle receives from sixty to eighty blows from a cast hammer on a cast-iron anvil; the latter must be accurate. Note cast iron, for in the first process wrought is preferred. Having received this hammering they are called "half finished," and then the whole contents of the bundle is placed on one side to cool. This we did by letting them remain in rack all night again. The processes above noted commenced at 3 A. M., and finished at 6 o'clock P. M.: the men—six—had done nothing but work at four bundles, *i. e.*, about 300 pieces of puddled bar. I kept my eyes particularly on two bundles, which now consisted of 150 sheets. Next morning at six these 150 sheets were cut to exact selling size, 56 inches by 28 inches, by hand shears, which they find to be cheaper than cutting by machine.

It will be remembered that in the last process the hot sheets were placed between cold ones; now the process was exactly reversed. Our 150 sheets were cold, a hot bundle of 150 sheets was brought, and two bundles made up, each of 75 old hot sheets and 75 new cold sheets, in process of manufacture, care being taken not to put in the hot sheets whilst any appearance of redness remained. These bundles were then taken again to the polishing hammer, and each received in four to five minutes 140 to 150 blows. The hammerman declared from observing the motion of the plates they were now ready; the bundles were opened and we found certainly fine polished sheets. The working tool sheets being removed, the new sheets were taken to the store and subjected to a thorough examination, near 30 per cent. being condemned as "brack." Taking 180 pieces of puddled bars the result was as follows: We got 160 sheets; out of these 160 we lost 12 in the first processes by holing, cracking, &c., and on reception in magazine 43 were thrown out as imperfect from cracks, spots, or blemish in polish. The remaining 115 sheets were divided into two categories: (1) where polish was good, *i. e.*, equal all over the sheet, 67; (2) where generally polish was good, but not entirely equal, 48. The rest were considered "brack," and sold at about £2 per ton cheaper, for makers of small articles, on the spot.

Conversing with the men, they say formerly they considered the polish was produced by the blow of the tilt hammer giving a gliding motion to the sheets; hence the name of "glance" iron. It was also held as an article of faith that after every reheating powdered charcoal must be used. This is not the case, for sheets quite as good are pro-

duced without; but the men are paid on the production, and hence the managers allow them their own way. I saw a bundle of sheets done without the charcoal and without the dipping, the results being exactly the same. The covering sheets were not much burnt, the heat of furnace being only moderate.

DAMP: ITS CAUSES, EFFECTS, PREVENTION AND CURE.

From "The Builder."

Under this title M. G. Philippe, a civil engineer officially employed by the municipality of Rouen, has contributed to *Les Travaux Publics* a series of valuable and interesting papers, of which we reproduce the principal points. The subject is of universal and individual interest, and of even greater importance in the climate of England than in that of France.

The *causes* of damp in buildings are —1, the presence of water in the atmosphere and the soil; 2, the porosity of building materials, which absorb it.

Its *effects* are only too well known, and may be classified as—1, disintegration of masonry, with injury to wall papers and other similarly-placed decorations; 2, decay of timber, and injury to wooden furniture; 3, development of saltpetre on walls, with injury to wall decorations; 4, injury to health of inhabitants.

The decay of timber used in building often carries with it an especial danger in France, because there chestnut wood is frequently employed for large beams; and as this wood decays first at the heart, while the outside remains sound, no superficial examination will give warning when an important piece of timber may be about to give way.

The development of saltpetre results from drying after damp. It is well known that this substance can be obtained from old building materials, and the white patches which it forms upon perfectly sound walls are familiar. During the siege of Paris, in 1870, the possibility of utilizing it for military purposes was taken into consideration, and a committee was appointed to investigate the amount obtainable in this way in case of necessity. It reported that the production of saltpetre in a building was in direct proportion to its age and uncleanliness. This conclusion appears very obvious, when we remember that saltpeter consists of potash, combined with nitric acid, and that nitric acid is azotate of ammonia. Kuhlmann, a distinguished chemist, proved by experiment that ammonia contained in a porous body is oxidized by contact with the air, and becomes azotate of ammonia. Fermenting vegetable and animal matter everywhere furnishes ammonia, building materials are the porous body required, and all clays contain potash; so that all the component parts of saltpeter are ready to hand, and as soon as the moisture which has held it in solution is evaporated by drier air the salt appears upon the surface. It is not necessary that ammonia should be present in any offensive form; rain will contain it, and fogs (especially town fogs) carry it in comparatively large quantities.

The prevention and cure of damp may be attempted by—(1.) employment of suitable materials for cellars, and other parts of buildings below or on the level of the soil; (2.) damp-courses to stop the upward progress of damp; (3.) preparations of different natures, either to protect the face of an exposed wall from the weather, or to prevent damp in the wall from affecting an apartment; (4.) precautions against infiltration.

The most thoroughly sanitary foundation for a building is concrete; and the author recommends covering the whole level of the future building with a layer 4 in. thick, composed of two-thirds broken flints well washed, and one-third mortar made of lime and gravel sand. He estimates such a layer would cost about 2½d. per square foot.

Well-puddled clay forms a good and inexpensive foundation, in districts where it is easily obtained. A layer 8 in. thick should be spread over the site of the building, and extended for about 16 in. outside the walls; and the external 16 in. should be carried up with the wall until the level of the soil is reached. Clay

cannot, however, be used to form a dry flooring for old buildings, as can be done with concrete.

Various methods have been proposed and employed for destroying that porosity of building materials, which is one of the chief causes of the mischief. M. Sebille, a civil engineer in Paris, has patented a process for injecting materials (especially brick) with gas refuse, which penetrates their substance, and renders them impermeable by water, at the same time increasing their weight, and giving them a brown color. A wall built with bricks thus prepared is absolutely dry, and their price is only increased by about 3s. 4d, per 1,000. Good results have been obtained by immersing the materials in solutions of soap and alum successively, and by applying these two preparations to the thoroughly-scraped surfaces of the walls of buildings already standing. The result of the chemical re-action which follows is to fill the pores of the brick or stone with a fatty substance, which opposes the passage of water. The immersion costs about 1d. per cubic foot of material.

The method preferred by M. Philippe is to plunge the material with the hand into a solution of silicate of potash for a time, merely long enough to allow all the air-bubbles to disengage themselves from its surface, and then lay it aside for forty-eight hours before using. The additional expense is extremely small, and the results (according to his experience) very satisfactory.

Many varieties of cement and other material are employed for mixing with mortar, in order to render it impermeable by water; of these the principal are Vassy or Gariel cement, Vicat (from Grenoble), Portland, and Peterspense cements, ground brick, Pozzolana (volcanic), wood ashes, calcined oyster-shells, etc. The greatest additional expense from using any of these is from 3d. to 7d. per cubic foot of masonry. A layer of such cement 1 in. thick, lining the walls of cellars, etc., is very useful, and costs on an average a little over 3d. per square foot. M. Philippe does not recommend French Portland cement, which is prepared chiefly at Boulogne, and which is much used in the North of France, as it very perfectly excludes damp, and is easily penetrated by saltpeter. Of French cements he prefers the most expensive—that of Vassy. For application to damp walls, solutions of soap and alum, used one after the other, have already been mentioned. Another substance which has proved useful for the purpose is gas tar. The wall must be well scraped, heated in parts by means of a hand stove, and the tar applied with a brush as hot as possible. It then penetrates into the pores, and hardens in cooling, forming a crust which arrests the passage of damp and saltpeter. The cost is very trifling.

An important and interesting piece of work of this kind was performed about the year 1813, under the direction of MM. Darcet and Thénard; and as their methods have not been surpassed, we quote a portion of their own account, extracted by M. Philippe from vol. 32 of the "Annales de Chimie et de Physique":

In that year, "M. Gros undertook to paint the cupola of the church of Sainte Genevieve. The surface had been prepared like a canvass, with a layer of strong size, covered with white lead mixed in drying oil. M. Gros consulted us upon the durability of this composition, and we did not hesitate to declare that it was far from offering the desired security against damp. After consideration and experiment, we adopted the following method. All the previously applied preparation was entirely removed; portions of the interior of the cupola were then successively and highly heated by means of a large gilder's stove, and our preparation applied with a large pincers, at a temperature of about 212° Fahr. To facilitate its absorption, the wall was re-heated once or twice during the process. Successive coatings were applied until no more could be absorbed. When dry, a coating of white lead mixed in oil was superposed, upon which the painting was to be executed. The preparation used consisted of one part of wax and three parts of boiled oil, with one-tenth its weight of litharge. The heat employed must merely stop short of carbonizing the oil."

The same process was applied by its inventors to two damp underground rooms at the Sorbonne. The mixture was slightly different, consisting of one

part oil prepared with litharge, and two parts resin melted in the oil—an operation of some delicacy. The plaster was allowed to remain on the walls, and they were thoroughly dried with a gilder's furnace, which, by an ingenious arrangement, was made to move along the wall at a fixed distance from it, and at any height. When dry they were again heated for the application of the varnish, as in the preceding case. Five coatings were absorbed; the sixth was partially absorbed, and formed a smooth hard surface to the wall. The cost of the process is chiefly that of the labor; the value of the materials being about 1d. per square yard.

M. Philippe proceeds to make suggestions and give opinions on various points of detail, some of which we reproduce.

Parquets may be preserved by laying them upon bitumen. This invention was patented by M. Gourguechon, but his patent has expired. It has been successfully varied by laying down a well-smoothed bed of cement, then applying a thin layer of asphalte to a portion at a time, and laying down the parquet before the asphalte had cooled. The only difficulty with these methods is that they cannot be used with pieces of parquet much exceeding one yard in length. The frames by which the parquet is held should be fastened to rows of spaced bricks, and the intervals filled up with pebbles, cinders, or other dry and healthy material, avoiding sawdust, old plaster, and similar matters.

Ventilating Bricks on the Flagedé system may be made on the spot in a mill supplied by the inventor, at the rate of from 300 to 400, per day, of almost any materials that may be at hand—plaster, conglomerate, brick earth, even of *torchis* (clay mixed with straw and grass). They admit air to the interior of the walls, and thus keep them dry. Their size is double that of bricks, and their price comes to about £1 per 1,000.

The *Journet patent* for dry floors or areas consists in laying down a bed of cement about 2 in. thick, in which small pipes are laid at about 1 in. apart, and then covered with another 2 in. layer. When the cement begins to harden the pipes are drawn out by the end, leaving hollow tubes through which the air can circulate if proper openings are provided in the walls.

Silicate applied to the surface of buildings renders them almost impervious to the action of weather. It has been applied by M. Kuhlmann to the principal monuments in the town of Lille, and to the new buildings of the Louvre in Paris, with the additional good result of harmonizing their tone with that of the older portions. It costs about 10d. per square yard for three successive applications at twenty-four hours' interval. M. Mignot has invented a cheaper preparation, colored to suit the different kinds of stone. It is to be noted that silicates cannot be used upon walls where saltpeter has been or is likely to be developed.

Enduits have been invented in great variety by different makers. A very excellent one, called Glyco metallic liquid, is prepared by MM. Caron et Dupuis. It prevents all action of damp on cement and plaster, by neutralizing the alkaline salts which they contain, and can be painted on with perfect security. Old walls should be well cleaned before it is applied; new ones will require three coats, which will cost about 9d. per square yard. An excellent preparation of gutta-percha is supplied by the Maison Gaudri, in Paris, for the same purpose, and costs about the same price.

Windows are one of the principal avenues of damp into apartments. One cause of this is the bad quality of the stone often employed. It should be as hard as can be obtained; or it might be covered with zinc, or coated with a good cement. Small leaden gutters may be placed inside the windows, to catch and carry off the rain which penetrates. This plan is particularly recommended for the windows of kitchens and bath-rooms, where the steam condenses on the glass in considerable quantity.

For *slates*, M. Philippe recommends either the Fourgeau or Chevreau system of hooks in preference to the ordinary method of nailing—which makes a hole through which damp penetrates.

Drains from closets should be furnished with a ventilating pipe, carried up with the chimneys, or which may (as at the Hôpital St. Louis and the old Hôtel Dieu at Paris) open direct into the kitchen flue, thus being always secure of a strong upward draught. In this way all unpleasant smells are obviated.

STRENGTH AND DUCTILITY OF THE COPPER-TIN-ZINC ALLOYS.

By ROBERT H. THURSTON.

Presented to 13th Annual Convention of American Society of Civil Engineers.

II.

The following tables record the results of tests made at the Physical Laboratory of the Stevens Institute of Technology at Hoboken:

5. Record of Tests by Tension.

Copper..80%
Zinc.....20%

ALLOY OF COPPER AND ZINC.

Lab. No. 585B.

Dimensions. Original and Final.	
Length. L, L′	Diameter. H, H′
5″	.798

Stresses.		Proof Load per Square Inch Area of		Breaking Load per Square Inch.		Extension.
Proof.	Ultimate.	Original section P	Fractured section. P′	Original section. T	Fractured section. T′	Actual.
4800	....	....	....	....	....	.0018
5000	....	....	....	....	....	.0037
5200	....	....	....	....	....	.0075
5400	....	....	....	....	....	.0132
5600	....	....	....	....	....	.0205
6000	....	....	....	....	....	.0385
220	....	....	....	....	....	.0127
6400	....	....	....	....	....	.0622
6800	....	....	....	....	....	.0904
8000	....	....	....	....	....	.1849
8800	....	....	....	....	....	.2450
9600	....	....	....	....	....	.2979
10400	....	....	....	....	....	.3530
11200	....	....	....	....	....	.4495
11600	....	....	....	....	....	.4880
12000 (*a*)	....	....	....	....	....	
16750 (*b*)	16750	33140	55599	33140	55599	

(*a*.) Micrometer slipped, further reading of no value.
(*b*.) Total elongation, measured after breaking 1.62″.

6. RECORD OF TESTS BY TRANSVERSE STRESS.

Copper.... 80%
Zinc....... 20%

ALLOY OF COPPER AND ZINC.

Lab. No. 585.

Dimensions: Distance between supports.	Breadth. b.	Depth. d.
22″	.995	.985

Proof stresses.	Deflection.	Breaking load.		Modulus of elasticity.
Absolute. P_1	Actual.	Absolute. P	Modulus. $R=\frac{3Pl}{2db_2}$	$E=\frac{Pl_3}{48\delta 1}$
10	.0042	....	....	
40	.0124	....	....	9030560
80	.0206	....	....	10708667
120	.0296	....	....	11349217
160	.0363	....	....	12339278
200	.0449	....	....	12469814
3	.0056			
240	.0544	....	....	12530618
280	.0692	....	....	11327350
320	.0980	....	....	9141138
360	.1659	....	....	6074807
400	.3288	....	....	3405686
3	.2445			
400	.3352			
420	.4414			
440	.5885			
460	.7520			
480	.9590			
500	1.1763	....	....	1189949
520	1.5463			
540	1.6163			
560	1.86			
580	2.22			
600	2.62			
620 (*a*)	3.27	620	21193	

(*a*). Bent down without breaking; bar removed.
Fracture, "Surface in character resembling No. 584, but less jagged." Color: brass yellow.

7. Record of Tests by Tension.

Copper.... 62.5
Zinc....... 37.5

ALLOY OF COPPER AND ZINC.
Lab. No. 609 A.

Dimensions. Original and Final.		Stresses.		Proof load per square inch area of		Breaking load per square inch.		Extension.
Length. L,L′	Diameter H,H′	Proof.	Ultimate.	Original section. P	Fractured section. P′	Original section. T	Fractured section. T′	Actual.
5″	.798	500						.0003
		1000						.0007
		1500						.0010
		2000						.0016
		3000						.0024
		4000						.0037
		5000						.0052
		6000						.0066
		100						.0008
		7000						.0087
		8000						.0123
		100						.0047
		9000						.0185
		10000						.0447
		100						.0359
		11000						.0810
		12000						1290
		100						.1162
		13000						.1782
		14000						2375
		100						.2197
		15000						.3148
		16000						.3877
		100						.3650
		16500						.4334
		17500 (a)						
	.670	24380(b)	24380	48760	68979	48760	68979	1.55″

(a). Micrometer slipped.
(b). Broke 2 inches from "C" end. Fracture ; light brownish yellow, very compact, diagonal surfaces slightly polished. Several times during the test a dull sound was heard from the piece, and at the same instant the resistance decreased, in one instance to the extent of 1,300 pounds.

8. Record of Tests by Transverse Stress.

		Dimensions.		
Copper....62.5% Zinc.......37.5%	ALLOY OF COPPER AND ZINC. Lab. No. 608.	Distance between supports.	Breadth. b.	Depth. d.
		22″	.970	.972

Proof stresses. Absolute. P_1	Deflection. Actual.	Breaking load. Absolute. P	Breaking load. Modulus. $R=\frac{3Pl}{2bd_2}$	Modulus of elasticity. $E=\frac{Pl_3}{48\delta I}$
10	.0044	....	....	
20	.0061	....	....	
40	.0078	....	....	15325081
80	.0167	....	....	14315643
120	.0244	....	....	14697004
160	.0327	....	....	14622094
200	.0417	....	....	14332809
3	.0040	....	....	
240	.0506	....	....	14174185
280	.0598	....	....	13992465
320	.0690	....	....	13859204
360	.0775	....	....	13881558
400	.0874	....	....	13677164
3	.0023	....	....	
440	.0958	....	....	13757029
480	.1028	....	....	13953576
520	.1102	....	....	14101299
560	.1198	....	....	13969106
600	.1318	....	....	13604210
3	.0048	....	....	
640	.1493	....	....	12810242
680	.1630	....	....	
720	.1832	....	....	11771840
760	.2130	....	....	
800	.2628	....	....	9097079
3	.0760	....	....	
840	.3160	....	....	
880	.4461	....	....	
920	.6000	....	....	4978218
960	.7782	....	....	
1000	.8927	....	....	3347588
3	.7277	....	....	
1040	1.1753	....	....	
1080	1.53	....	....	2109413
1120	1.88	....	....	
1160	2.23	....	....	
1200 (a)	3.13	1 200	43 216	1145709

(a) Bar bent down without breaking.

9. Record of Tests by Tension.

TRIPLE ALLOY OF COPPER, TIN AND ZINC.

TOBIN'S ALLOY.

Copper.... 58.22%
Tin........ 2.30%
Zinc ...... 39.48% Lab. No. 856B.

Dimensions. Original and final.	
Length. L, L′	Diameter. D, D′
5″	.798

Stresses.		Breaking load per square inch.		Extension.
Proof	Ultimate.	Original section. T	Fractured section. T′	Actual.
150				0
500				.0012
1000				.0022
1100				.0024
1200				.0026
1300				.0028
1400				.0030
1500				.0032
1600				.0034
1700				.0036
1800				.0038
1900				.0041
2000				.0044
2500				.0054
3000				.0064
3500				.0074
4000				.0081
4500				.0088
5000				.0095
150				.0022
5000				.0113
6000				.0125
7000				.0137
8000				.0150
9000				.0165
10000				.0176
11000				.0189
12000				.0202
13000				.0213
14000				.0226
15000				.0240
16000				.0254
17000				.0268
18000				.0282
19000				.0297
20000				.0313
150				.0150
5000				.0215
10000				.0279
15000				.0345
20000				.0399
21000				.0423
22000				.0447
23000				.0473
24000				.0494
25000				.0527
26000				.0568
27000				.0615
28000				.0674
29000				.0771
30000				.0873
31000				.0958
32000				.1277
33000				.1577
33800 (a)	33800	67690	73160	

(a) Broke. Fracture; yellowish gray, with light pinkish shade. Open granular structure, with a few very minute blow holes, several lustrous points scattered over the surface. No radiated lines were seen like those of the transverse fracture.

10. Record of Tests by Transverse Stress.

TRIPLE ALLOY OF COPPER, TIN AND ZINC.

TOBIN'S ALLOY.

Copper....58.22%
Tin....... 2.30%
Zinc......39.48%

Lab. No. 856.

Dimensions.		
Distance between supports.	Breadth. b.	Depth. d.
22″	1.010	.992

Proof Stresses.	Deflection.	Breaking Load.		Modulus of Elasticity.
Absolute. P_1	Actual.	Absolute. P	Modulus. $R=\frac{3Pl}{2bd_2}$	$E=\frac{Pl_3}{48\delta I}$
3				
10	0.0024			
20	0.0046	....	....	11760504
40	0.0098	....	....	11040471
80	0.0202	....	....	11712635
120	0.296	....	....	10965874
160	0.418	....	....	10353743
200	0.0517	....	....	10643891
10	.0032			
3	.0011			
200	.0532			
240	.0612	....	....	10607511
280	.0712	....	....	10637306
320	.0802	....	....	10792679
360	.0908	....	....	10724336
400	.1000	....	....	10819661
10	.0027			
3	.0008			
400	.1010			
440	.1095	....	....	10869067
480	.1197	....	....	10846777
520	.1291	....	....	10869829
560	.1403	....	....	11578364
600	.1511	....	....	14321161
10	.0032			
3	.0015			
600	.1515			
640	.1629	....	....	10627046
680	.1740	....	....	10570954
720	.1846	....	....	10550048
760	.1944	....	....	10574771
800	.2038	....	....	10617922
10	.0043			
3	.0032			
800	.2028			
840	.2142	....	....	10607511
880	.2247	....	....	10593349
920	.2344	....	....	10616562
960	.2453	....	....	10672909
1000	.2550	....	....	10607511
10	.0064			
3	.0046			
1000	.2544			
1040	.2642	....	....	10647661
1080	.2764	....	....	10569132
1120	.2847	....	....	10641044
1160	.2951	....	....	10632674
1200	.3062	....	....	106[illegible]0509
10	.0114			
3	.0093			
1194*	.3069			
1240	.3170			

* After 55 minutes resistance decreased from 1200 to 1194 pounds.

10. Record of Tests by Transverse Stress.—*Continued.*

TRIPLE ALLOY OF COPPER, TIN AND ZINC.

TOBIN'S ALLOY.

Copper....58.22%
Tin........ 2.30%
Zinc.......39.48%

Lab. No. 856.

Dimensions.		
Distance between supports.	Breadth. b.	Depth. d.
22″	1.010	.992

Proof Stresses. Absolute. P_1	Deflection. Actual.	Breaking Load. Absolute. P	Breaking Load. Modulus. $R = \frac{3Pl}{2bd^2}$	Modulus of Elasticity. $E = \frac{Pl^3}{48\delta I}$
1280	.3276			
1320	.3398			
1360	.3528			
1400	.3673	....	....	10310049
10	.0210			
3	.0193			
1400	.3695			
1440	.3817			
1480	.3959			
1520	.4102			
1560	.4236			
1600	.4395	....	....	9847245
10	.0407			
3	.0387			
1600	.4405			
1640	.4537			
1680	.4704			
1720	.4882			
1760	.5042			
1800	.5205	....	....	9354174
10	.0743			
3	.0727			
1800	.5236			
1840	.5383			
1880	.5586			
1920	.5823			
1960	.6076			
2000	.6343			
10	.1340			
3	.1326			
8(*a*)				
3	.1329			
2000	.6350	....	....	8955262
2040	.6594			
2080	.6856			
2120	.7140			
2160	.7456			
2200	.7777	....	....	7651812
2240	.8106			
2280	.8621			
2272(*b*)	.8621			
2268(*c*)	.8621			
2260(*d*)	.8621			
2256(*e*)	.8621			

(*a*) After 10 minutes resistance increased from 3 to 8 pounds.
(*b*) " 1 " " decreased " 2280 " 2272 "
(*c*) " 3 " " " " " " 2268 "
(*d*) " 25 " " " " " " 2260 "
(*e*) " 60 " " " " " " 2256 "

10. RECORD OF TESTS BY TRANSVERSE STRESS.—(*Continued.*)

TRIPLE ALLOY OF COPPER, TIN AND ZINC.

Copper......58.22%
Tin........ 2.30%
Zinc........39.48%

TOBIN'S ALLOY.

Lab. No. 856.

Dimensions.		
Distance between Supports.	Breadth. b.	Depth. d.
22″	1.010	.992

Proof Stresses.	Deflection.	Breaking Load.		Modulus of Elasticity.
Absolute. P_1	Actual.	Absolute. P	Modulus. $R=\frac{3\,P\,l}{2\,b\,d_2}$	$E=\frac{P\,l_3}{48\,\delta\,I}$
2288 (*f*)	.8665 (*f*)			
2290	.8658			
2300	.8722			
2310	.8763			
2320 (*g*)	.8843 (*g*)			
2312 (*h*)	.8843			
2309 (*i*)	.8843			
2260 (*j*)	.8770 (*k*)			
2270	.8867			
2280	.8893			
2290	.8919			
2300	.8948			
2310	.8967			
2320	.8990			
2330	.9019			
2340	.9063			
2350	.9165			
2342 (*l*)	.9165			
2350	.9189			
2360	.9239			
2370	.9418			
2380	.9529			
2390	.9650			
2400	.9764			
2410	.9888			
2420	1.0048			
2430	1.0189			
2440	1.0333			
2450	1.0438			
2460	1.0553			
2470	1.0755			
2480	1.0865			
2490	1.1013			
2500	1.1265			
2510	1.1341			

(*f*) to (*g*) presents slight elevation of Elastic Limit.
(*h*) Resistance decreased in 3 minutes from 2320 to 2312 pounds.
(*i*) " " " 10 " " " " 2309 "
(*j*) Resistance decreased in 66 hours 13 minutes from 2320 to 2260 pounds.
(*k*) Reading of extension apparatus changed, so as to correspond to deflection of 8770—probably caused by gradual set of machine under the constant strain, and compression or bending of the lower transverse timber.
(*l*) Resistance decreased in ten minutes from 2350 to 2342 pounds.

10. Record of Tests by Transverse Stress.—(*Continued.*)

TRIPLE ALLOY OF COPPER, TIN AND ZINC.

Copper......58.22%
Tin........ 2.30%
Zinc... ....39.48%

TOBIN'S ALLOY.

Lab. No. 856.

Dimensions.		
Distance between Supports	Breadth. b.	Depth. d.
22″	1.010	.992

Proof Stresses.	Deflection.	Breaking Load.		Modulus of Elasticity.
Absolute. P_1	Actual.	Absolute. P	Modulus. $R=\frac{3\,P\,l}{2\,b\,d_2}$	$E=\frac{P\,l_3}{48\,\delta I}$
2520	1.1475			
2530	1.1647			
2540	1.1818			
2550	1.1918			
2560	1.2073			
2570	1.2293			
2580	1.2445			
2590	1.2585			
2600	1.2851	....	....	54[illegible]
2610	1.3063			
2620	1.3288			
2630	1.3406			
2640	1.3556			
2650	1.3747			
2660	1.3973			
2670	1.4178			
2680	1.4447			
2690	1.4665			
2700	1.4898			
2720	1.5057			
2730	1.5303			
2740	1.5603			
2750	1.6106			
2760	1.6279			
2770	1.6395			
2780	1.6581			
2790	1.6899			
2800	1.7285	....	....	4331697
2810	1.7599			
2820	1.7793			
2830	1.8111			
2840	1.8553			
2850	1.8807			
2860	1.8936			
2870	1.9453			
2880	1.9881			
2890 (*m*)	. ....	2880	95623	

(*m*) Broke in the middle in putting on strain. Gave warning by a slight crackling sound a few seconds before breaking, and broke gradually.

Fracture: Yellowish gray, with slight pinkish tinge, somewhat like brass alloy No. 612, but more yellow. Coarse granular structure, with radiated fibers near the edges. Slightly lustrous. Fractured section—trapezoidal.

11. Record of Tests by Transverse Stress.

TRIPLE ALLOY OF COPPER TIN AND ZINC.

Lab. No. 1001.

Copper..........55.00%
Tin............ 0.50%
Zinc............44.50%

Dimensions.		
Distance between Supports.	Breadth. *b.*	Depth. *d.*
22″	1.″	.979″

Proof Stresses.	Deflection.	Breaking Load.	
Absolute. P_1	Actual.	Absolute. P	Modulus. $R=\frac{3\,P\,l}{2\,b\,d_2}$
3			
10	.0021		
20	.0051		
40	.0122		
80	.0417		
120	.0321		
160	.0417		
200	.0519		
10	.0024		
3	.0004		
200	.0520		
240	.0631		
280	.0734		
320	.0813		
360	.0899		
400	.1001		
10	0.0028		
3	.0008		
400	.0997		
440	.1102		
480	.1199		
520	.1300		
560	.1402		
600	.1516		
10	.0046		
3	.0018		
600	.1518		
640	.1623		
680	.1745		
720	.1881		
760	.2024		
800	.2164		
10	.0140		
3	.0119		
800	.2167		
840	.2296		
880	.2443		
1400			
3(*a*)	.3089		
10	.3097		
3	.3057		
....	....	2100	72308

(*a*.) No. 1001 (55 Cu. 0.5 Sn, 44.52 n.) The scale beam could not be raised by applying more pressure after 2,100 pounds was reached. This was due to the rapid bending of the bar, which, however, could not be broken until it was nicked with a saw on all sides. The casting was not very sound externally, and the corners were somewhat rounded, owing to the metal not having filled the mould completely. After 1,400 lbs. was reached and applied, a test was made to determine the recovery from set with time. When balanced at lbs. the micrometer read 0.3089″. After 20 minutes the scale beam balanced at 5½ lbs., and after 15 hrs. 45 minutes at 10 lbs. The reading of the micrometer was again taken, it being this time 0.3094″, showing a difference of .0005, which may be ascribed to the gradual recovery or springing back of the wooden frame of the machine after it was relieved from pressure. When the pressure of 5 5 lbs. was taken off and the scale beam again balanced at 3 lbs., a reading of 0.3057 was obtained, which indicates a recovery from set of 0.3094″—0.3057″=0.0037″ in 15¾ hours.

12. Record of Tests by Tension.

Copper, cast very hot. Cast Copper.

Lab. No. 581A.

Dimensions. Original and Final.	
Length L, L	Diameter. H, H′
5″	.798

Stresses.		Proof Load per Square Inch Area of		Breaking Load per Square Inch.		Extension.
Proof.	Ultimate.	Original Section. P	Fractured Section. P′	Original Section. T	Fractured Section. T′	Actual.
400						.0004
600						.0007
1000						.0011
2000						.0022
3000						.0025
4000						.0027
5000						.0026
6000						0032
6800						.0083
7200						.0132
8000						.0258
8400						.0492
8800						.0642
9200						.0792
9600						.0942
9800						.1073
250						.0951
9800						.1082
10200						.1218
10600						.1408
11000						.1605
11400						.1794
11800						.2008
12200						.2191
12600						.2405
13000						.2626
14000						.3058
270						.3155
14000						.3270
14400						.3448
14600 (*a*)	14600	29200	34790	29200	34790	.3760

(*a*.) Broke while reading was being taken. Broke ¼ inch from "A" end. The fractured section distorted from circular form. Three diameters measured .737″ .725″ and .732″. Fracture: fine, fibrous looking, radiated and compact. Strongest piece of copper yet tested.

13. Record of Tests by Transverse Stress.

Cast Copper.

Copper, cast very hot.

Lab. No. 581.

Dimensions.		
Distance between Supports.	Breadth. b.	Depth. d.
22″	.990	.980

Proof Stresses. Absolute. P_1	Deflection. Actual.	Breaking Load. Absolute. P	Breaking Load. Modulus. $R=\frac{3Pl}{2bd_2}$	Modulus of Elasticity. $E=\frac{Pl^3}{48\delta I}$
10	0.0033			
40	.0116	....	....	9851369
80	.0224	....	....	10203205
120	.0355	....	....	9657120
160	.0513	....	....	8910400
200	.0729	....	....	7837853
5	.0260			
240	.0964	....	....	7112607
280	.1280			
320	.1705	....	....	5361919
360	.2253			
400	.3079	....	....	3711460
5	.2040			
440	.4169			
480	.5565			
520	.7540	....	....	1970274
560	.9155			
600	1.1635			
5	1.0085			
600	1.2105			
640	1.37			
680	1.63			
720	1.93	....	....	1065786
760	2.23			
800	2.60			
820	2.83			
840	3.09			
860(*a.*)	3.49	....	....	720375
1150(*b.*)	5.74			
3000(*c.*)	8.00	3000	29848	

(*a.*) The supports slipped. Placed the bar on cast iron fixed supports 20 inches apart, and (*b.*) 1 150 lbs. gave it a further deflection of 2¼ inches. Moved the supports to 10 inches, and applied (*c.*) 3 000 lbs., when bar broke, the total deflection being about 8 inches.

Fracture: Coarsely fibrous and radiate from center of surface of fracture. Color: Dark red from superficial oxidation. Fibers interrupted and covered over with minute ridges, with sharp lines of separation.

14. Record of Tests by Compression.

Copper, cast very hot. CAST COPPER.

Lab. No. 581.

Dimensions. Original and Final.		Stresses.		Proof Load. Per Square Inch Area of Original Section.	Breaking Load. Per Sq. Inch Original Section.	Compression.
Length. L, L′	Diameter. H. H′	Proof.	Ultimate.	P	T	Actual.
2″	.625	500				.0026
		1000				.0046
		2000				.0079
		3000				.0109
		4000				.0143
		5000				.0177
		6000				.0212
		7000				.0263
		8000				.0347
		9000				.0513
		10000				.0801
		11000				.1187
		12000				.1619
		13000				.2053
		14000				.2508
		15000				.2942
		16000				.3373
		17000				.3373
		18000				.4722
		19000				.4688
		20000				.5100
		21000				.5594
		22000	22000	71709	71709	.6415

THE ACTUAL LATERAL PRESSURE OF EARTHWORK.

By BENJAMIN BAKER, M. Inst. C.E.

Proceedings of the Institution of Civil Engineers.

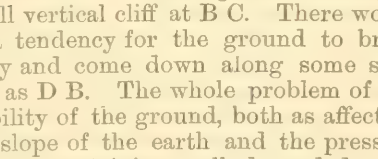
III.

DISCUSSION.

Mr. B. Baker desired to add, that his object in bringing forward the paper was not so much to present certain facts for criticism as to induce others to give the results of their experience, and if every one helped a little he thought a very useful result would be attained.

Mr. W. Airy said he had given considerable thought and attention to the subject of earthwork, and he considered the collection of examples in the paper would make it an extremely useful one for purposes of reference. The subject of earthwork was a very difficult one to deal with, and he wished to point out briefly in what this difficulty consisted. A B C D (Fig. 42) might be taken to be

Fig.42



the section of some ground having a small vertical cliff at B C. There would be a tendency for the ground to break away and come down along some such line as D B. The whole problem of the stability of the ground, both as affecting the slope of the earth and the pressure against a retaining wall, depended upon the accurate determination of the line D B. It was not an exceedingly difficult matter to determine this line, if the constants of cohesion, friction, and weight of the ground were known; and he had himself dealt with the problem in a paper communicated to the Institution. The mechanical conditions of equilibrium were very simple; the force tending to bring the earth down was the weight of it; the forces tending to keep it from coming down were the friction along the line D B and the cohesion of the ground along that line. All those forces acted according to well-understood laws, and therefore if the constants of weight, cohesion, and friction of any particular ground were known, it was not difficult to find out the exact position of the line D B, and therefore the pressure on the retaining wall, or the shape of the slope. The question then arose, what was the real difficulty of constructing tables for practical use with regard to earthwork? Simply this, that the varieties of ground were infinite in number and very wide in range, and when that was the case it was quite idle to think of constructing tables for practical use. A man having a particular kind of earth to prescribe for, would not be able to ascertain by inspection what the constants of that earth were, and therefore he would not know whereabouts in a table to look; he would have to determine the constants for himself; and if he had to do that he had to do the whole work, and the tables were of no use to him. He thought the author had rather overlooked the enormous number of conditions of earth when he contrasted the small number of experiments upon earthwork with the large number of experiments made with timber. A piece of oak would give very nearly the same results for strength, elasticity, and so on, whether it was grown in Kent or in Yorkshire; and, therefore, when a few experiments had been made upon it, it was not necessary to repeat them over and over again. That was not the case with earthwork, because the conditions were so exceedingly variable. He exhibited a little rough machine he had used for testing earthwork and taking the cohesion of the ground. The block of wood might be taken to represent a block of raw clay taken out of a cutting. There was a common lever balance, and a couple of movable cheeks were fitted into chases cut in the sides of the clay block; and

the clay having been rammed in a box so that it could not move, weights were put in the scale until the head was torn off. After subtracting the weight of the piece that was torn off, and measuring the area of the cross section that was broken, the constant of cohesion was determined. For the constant of friction he arranged a certain number of blocks of the same clay in a tray, and scraped them off smooth; then he had another block of clay with a smooth surface which he put on it, and then tilted the tray until the loose block slid; that gave the coefficient of friction. He should like to refer to the exceedingly wide range of tenacity shown by different kinds of clay. In one set of experiments with ordinary brick loam, that clay gave a coefficient of cohesion of 168 lbs. per square foot, and a coefficient of friction of 1.15. With some shaley clay out of a cutting in the Midlands, he had found a coefficient of tenacity of 800 lbs. per square foot, and a coefficient of friction of 0.36. That was a very wide range, but it was only a part of what was actually to be found in practice.

Mr. L. F. Vernon-Harcourt wished to say a few words on the subject, as the author had referred to two or three works with which he had been connected. The author had pointed out, from the experiments he had recorded, that the pressure upon the back of a retaining wall was a good deal less than it was theoretically supposed to be—about one-half—but as he allowed a factor of safety of 2, it apparently came to very much the same thing. With regard to walls on a rubble mound, the author remarked that the base was in many cases small. That, he thought, was owing to two causes; first, that with a rubble mound for a base there was no chance of sliding; and secondly, that in those cases there was a rubble filling behind, which he supposed was about as good a material for backing as could be got. The slope of the inner face of the rubble mound of the breakwater at Alderney harbor had been referred to as $1\frac{1}{4}$ to 1; but it ought to be remembered that in that case the materials used were very large blocks of stone, and therefore the slope would be naturally steeper than under more ordinary conditions. Reference had also been made in the paper to St. Katharine's breakwater, Jersey, as an example of a wall built with a very small base. The author took the whole of the height of that wall as the proper height; but it would be observed that the top of the wall had what used to be called a promenade along it, and therefore the whole of the filling did not apply to the entire height of the wall. The author stated that the base was 28 per cent. of the height of the wall, but leaving out the promenade it would be 35 per cent. Of course it would be something intermediate, as there would only be the small piece of filling under the promenade to be taken into account additional, instead of what would be the filling at the back if it was filled up entirely to the top level. The author had referred to the West India dock wall, and stated that several portions of it had come forward.' That, however, was not quite the case. It was true that two portions of the south wall came forward—that two surfaces of clay at some little depth below the wall slid upon one another. Probably some seam of sand or silt was washed out by the water behind the wall from between two layers of clay, and in that way the two detached surfaces of clay were free to slide upon one another. He was quite certain of the exact position of the surfaces of rupture, because he saw the two surfaces of clay after the excavation was made for rebuilding the wall, and they were as smooth as glass. The remedy for that appeared to him to be very simple, and it was certainly successful in the case in point. The wall had failed, as the author had stated, not from any fault in the thickness or the weight, but simply owing to the sliding forward; and instead of adding any further weight to the wall, the foundations were carried down to a greater depth; but it only required 2 or 3 feet more in depth in the basin wall foundations that had to be executed afterwards under precisely similar conditions. That was quite sufficient to keep the wall in a perfect state of equilibrium without the least coming forward; and he should imagine that was decidedly better on the whole than adding to the weight of the wall. It appeared to him that practice was rather contrary to theory in giving too great a thickness to the top of the wall, and too small a

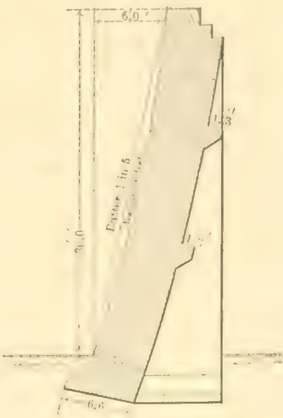
thickness, comparatively speaking, to the bottom; and that it would be better to have a wall more of the shape of the Sheerness wall a good deal lessened at the top, rather than a wall like those generally adopted, which had more parallel faces with a little additional thickness from the batter. He thought it would be better to make a wall narrower at the top and widening out more towards the bottom, and to bring the foundations of the wall well down into the ground so as to prevent any chance of sliding. In the case of the West India dock wall, besides the badness of the backing, there was a large amount of water that seemed to percolate from the Millwall docks, which were filled with water while the wall was being built, the docks not having been puddled. It was clearly shown that that had a considerable effect, because the north wall, though it was built in exactly the same manner, and though the water of the Export dock was really nearer, stood perfectly, as there was not the same amount of water pressure at the back, owing to the water being unable to penetrate through the silted-up bottom of the Export dock. He considered that the Institution was much indebted to the author for collecting and comparing so many valuable facts, as, whilst descriptions of particular works were very useful, it was by taking a general survey, from time to time, of the existing state of knowledge, in any special branch, that definite progress in engineering science was most likely to be promoted.

Mr. J. Wolfe Barry believed the statement was true, that the pressure against retaining walls did not approach to the theoretical thrust; at the same time he was of opinion that large retaining walls gave the engineer as much anxiety as any work he ever undertook. It should be remembered that, as a rule, the thrust which the walls had to bear came against them when the material of which they were composed was green, and unless contractors and others were very careful in strutting the new work, and allowing plenty of time for the material to set, there would be a condition of affairs in the early stages of the wall which would never arise after the materials were thoroughly consolidated. He wished to point out that it was for such reasons most engineers were now getting to realize the extreme desirability of using cement as much as possible. The early stages of engineering works were generally those in which the greatest risks were run, and if a slow-setting material were used, the strains would be exerted against it in its weakest condition, and disasters would occur such as would not happen at a later period. He agreed with the statement of the author with regard to the failure of retaining walls. No doubt, in ninety cases out of a hundred, the failure happened from bad foundations. The remedy in railway works was in many cases that shown in Fig. 17, which practically amounted to strutting the toe of the wall against the opposite wall, and so preventing it sliding forward. That was a very simple arrangement, and resembled in its effect the strutting of timber, which was generally carried out as a temporary measure by a contractor, when, an invert was going to be put in. If the engineer thought that a continuous invert could be dispensed with, a half measure, which was often perfectly good, was to adopt some of these struts—which, in fact, were a discontinuous invert, as shown in Fig. 17. In railway walls he thought engineers were a little too apt not to use struts above the trains, it being considered in many cases rather *infra dig.* to strut a wall. He could not see why it should be so. The horizontal strains exerted against the retaining wall about 14 feet or 15 feet high above its base were small; the struts consequently involved a very small expense, but they prevented all possibility of movement, and they saved a large amount in the cost of the wall. Having had something to do with the Metropolitan District railway, he could thoroughly corroborate the statement of the author, that the walls had stood remarkably well. As far as he knew, there was no sign of failure or incipient failure in any of them. There was, however, one little matter he had noticed, viz., that in many of the walls there was a small angular crack across the external angles of the piers. He did not know how the cracks had originated, but he thought they might be due to the action of frost; the corners getting saturated, the frost attacked the brickwork at the angles and broke them off. If so,

it rather pointed out that in such walls it might be desirable to round the angles, or have angular bricks and avoid the sharp corners.

Mr. W. B. Lewis said the experience gained in the construction of the Underground railway was so large that the profession naturally looked for the opinions of some of those who were concerned in it; and they all felt grateful for the fullness and ability with which those opinions had been expressed in the paper. He thought the paper was open to this reflection; that, whereas, the author in the earlier pages discredited the theoretical views that generally prevailed respecting retaining walls, in the latter part he stated that his practice had pretty well accorded with them. For instance, he gave the theoretical thickness for a retaining wall in ground that naturally stood at a slope of 1½ to 1 as 31 per cent. of the height; and in the last paragraph but one he said his habit had been to make his walls ⅓, or 33 per cent.; and in the Table with slopes from 1 to 1 to 4 to 1, which included all that engineers usually had to deal with, his theoretical thickness ran from 0.239 to 0.451, while in the concluding paragraphs of the paper he stated that the engineer must work between the limits of ¼ the thickness and ½, which seemed to agree with the theoretical thickness. The general conclusion that engineers must work between ¼ and ½ was different from the practice in which Mr. Lewis had been trained, and he had therefore brought a diagram (Fig. 43) of a retaining wall constructed according to Mr. Brunel's rules. Of course Mr. Brunel, who had to carry out very great works, modified his rules to suit the circumstances; but the diagram represented his standard section of wall such as was constructed at Lord Hill's land in the early days of the Great Western railway, and at the Britain Ferry docks two years before his death. It would be seen that the dimensions and peculiarities of that wall differed very much from those given in the paper. In the first place the wall had an average batter of 1 in 5, and at the top a batter of 1 in 10. Batter was a point on which Mr. Brunel always insisted, and Mr. Lewis was a little surprised that the author seemed to treat it with so much indifference. He was evidently aware of its value, because in the early part of the paper he mentioned a wall with a batter of 1 in 5, and a thickness of 1 foot, which he said was equivalent to a vertical wall of 1 foot 9 inches. Now anything that was equivalent to an increase of the original value of 73 per cent. was well worthy of consideration.

Fig. 43



Scale, 16 feet 1 inch.

Mr. Brunel's custom was to curve the face of the wall. The radius was 150 feet in the case of a 30-feet wall, or five times the height. The thickness was ⅕ to ⅙ the height. The counterforts were 2 feet 6 inches thick, and placed 10 feet apart from center to center, but were omitted in good clay cuttings. In the case of docks sometimes there was a difficulty, in consequence of the necessity of having the top more upright, and at Britain Ferry docks the radius was reduced by nearly one-half. Mr. Brunel, too, was in the habit of building behind what he called sailing courses, and the projections in Fig. 43 were 1 foot 3 inches. In the case of embankments the wall was supported by earth carefully punned against it and against the sailing courses, thereby adding considerably to the weight that had to be overturned when pressure came from behind. Then his rule for thickness was ⅙, which was below the minimum given by the author. There were a number of such walls at Paddington, Bath, Plymouth, Briton Ferry, 30 feet high and 5 feet thick, and generally of nearly the same thickness at the top as at the bot-

tom. Another point Mr. Brunel was particular about was that the footings were made square to the batter, and when the ground was not good considerably larger footings were introduced. At Briton Ferry a 2-feet lining of concrete was employed at some places for watertightness. Concrete was not then in such general use as it was at present. Of course when exceptional ground was met with it was dealt with exceptionally. At a tunnel on the Wilts, Somerset, and Weymouth railway, some heavy ground had been found; the tunnel mouth was in a 60-feet cutting, a retaining wall 30 feet high was built, and the top was sloped back at $\frac{3}{4}$ to 1, with a 2-feet covering of masonry, and the wall was built precisely of the dimensions represented by Fig. 43; but as the ground was heavy, the batter, instead of being 1 in 5, was 1 in 4, and that was the only alteration. That wall was built in 1854, had never given any trouble, and was standing at the present moment. It seemed to him that Mr. Brunel, forty years ago, came nearer to the teaching of the experiments and of the reasoning in the paper, than the author had ventured to do in his own practice.

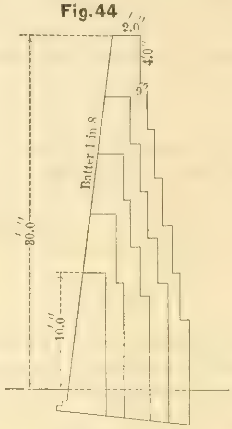
Mr. J. B. Redman observed that the author had undoubtedly filled a void in the literature of engineering; for, notwithstanding the great experience that most of the members of the Institution had of such catastrophes as those which had been referred to, it was only human like that they had not been often recorded by the designers of the works. Those who constituted what was now a select minority of the Institution would remember the partial failures of Mr. Robert Stephenson's retaining walls in the Euston cutting of what was then the London and Birmingham, and now the London and North-Western railway. Those partial failures were met by overhead horizontal girder struts supporting the walls, and it was rather curious that, notwithstanding all the experience that had been since gained, in a large number of instances, in metropolitan railways, the overhead girder had been, as it were, the natural sequence of what might be termed the unretaining wall. There was one circumstance which very much complicated the question of the direct lateral thrust of earthwork upon a retaining wall, and which rather curiously had not been mentioned by the author. It was incidentally referred to in the latter part of the paper, where the author said French engineers, in designing a wall at Marseilles, made the width of the base 58 per cent. of the vertical height, in consequence of the dip of the strata being towards the wall. In a large number of cases of the failures of retaining walls in open cuttings near London, he thought it would be found that the failure was entirely on one side. Where the dip of the strata was towards the cutting, and more especially if there were laminæ of clay, the superimposed strata often struck near the base of the wall; and a retaining wall on that side not only had to support the normal lateral thrust of the mass of earthwork immediately behind, but it had also a long wedge-like piece of earth impinging against the earth at the back of the wall, so that in many cases the thrust on the wall at the one side must be something like double the amount that it was on the other; because on the other side, the dip being away from the wall, the wall was subject only to the lateral thrust of the earthwork in its rear. The author had stated that the failures of many dock walls did not illustrate entirely the ordinary lateral thrust of earthwork; but Mr. Redman thought that such cases as the failure of the walls constructed by the late Mr. G. P. Bidder, Past-President Inst. C.E., at the Blackwall entrance to the Victoria docks, the partial failure of the same engineer's walls in the enlargement of the Surrey Docks, the similar catastrophe at the Victoria dock, Hull, in the work designed by the late Mr. John Hartley, and possibly also a similar movement in the South West India Dock wall, were all clearly attributable to lateral thrust. It might be said that the foundation was not taken down deep enough, and consequently the wall did not resist that thrust; but having had a somewhat extended and varied experience for a great number of years, he certainly was not prepared to indorse the dogma that a dock wall or a river wall must necessarily be so strong as to resist a head of water, or in width at the base equal to one-half the height. In the first place, the water ought not to be allowed to come behind the wall. There

were exceptional cases, perhaps, where that could hardly be avoided; but it seemed to him that laying down such a tenet was a premium for loose engineering, imperfect supervision, and lavish expenditure. He had himself, in the lower reaches of the Thames, erected some of the heaviest embankment walls on the river, where the thickness was only $\frac{1}{5}$ of the vertical height. It was true that the walls were founded on the best possible foundation Thames ballast—and it was done as tide work; and the greatest possible care was also taken to keep the backing up to the same level as the wall, and indeed rather above the wall. In fact, the great mistake in retaining walls was the imperfect supervision exercised over the backing. If the backing were put in with tolerably fair material in thin horizontal layers and brought up in that way, the lateral thrust was reduced to a very small matter. The author had stated that the decayed timber wharves on the Thames and in other neighborhoods showed that the lateral thrust must be over-estimated; but it should be remarked that the skin might be stripped off the face of the earthwork, assuming that no water was coming against it, and it would stand, because from the length of time and consolidation of material, there was no lateral thrust. The example quoted of the breakwater at St. Katherine's, Jersey, appeared to be a case in point. He had nothing to do with the inception or execution of that work; but he thought the wall might be taken down and the heart of the pier would still stand. He would refer to two great Metropolitan failures which were well known, and which might be interesting in illustration of this subject. One was that of Greenwich Pier and the other of the Island Lead Works. The Greenwich Pier was constructed nearly half a century ago from the design of a local architect, Mr. Martyr. It was one of the heaviest embankments on the Thames; it had the greatest depth of water up to it, and it was, being in the hollow of the reach, subject to every condition of weather. The base was formed by cast-iron piling and cast-iron sheeting between, constituting a half-tide dam, and concrete was got in behind. Upon the top of the concrete there were large 6-inch York landings and a very solid, heavy brick wall. There were also outer piles, and the work was constructed in the best possible way. The case was somewhat complicated by the fact that a large amount of land-water came down and a large amount of spring water. There was a common sewer running through the heart of the work, and a large tidal reservoir for the Ship Hotel. The whole of that work, with the exception of the two returns and quoins and a small portion in front of the Ship Hotel, slipped into the river during the night some forty years back. The late Mr. Chadwick, who built the Hungerford suspension bridge, entered into a contract to restore the work on his own plan, acting as engineer and contractor, and he restored the portion that had failed with timber-bearing piles and a solidly constructed brick wall. Shortly after the demise of Mr. Chadwick, the restored portion showed signs of failure, and Mr. Redman was called in by the Pier Directorate, and the matter resulted in a lawsuit, and a large sum of money was obtained in compensation. All he did was to bleed the pier by inserting a cast-iron pipe with a self-acting flap at the eastern end, and to remove and substitute with better material some part of the backing. He proposed driving land-tie piles at the back and some in front; but on consideration with the Directorate, it was thought that driving piles might be a ticklish operation. That was twenty years ago, and up to the present time the work had remained in the same state. It had settled somewhat at the eastern end, and there were reopened fissures in front, so that the movement had not altogether ceased. The wall of the Island Lead Works designed by the late Mr. R. Sibley, M. Inst. C.E., was the pioneer of cast-iron wharfing; and from the fact of the Limehouse cut having been deepened too close up to it, the wall failed. As the author had said, that case did not illustrate the absolute lateral pressure of earthwork, because this work, as long as it was not meddled with, stood satisfactorily. The leaseholders called in Mr. Redman on that occasion, and the freeholder consulted Mr. Bateman, Past-President Inst. C.E., and the late Mr. N. Beardmore, M. Inst. C.E., very wisely—to avoid a lawsuit—con-

structed a wall deeper down, to their satisfaction.

Mr. W. Atkinson agreed with Mr. Lewis's remarks with respect to the large amount of masonry or brickwork that the author had introduced in the cases of the metropolitan railways. He had been much struck with the proportion of $\frac{1}{3}$ of the height for the mean thickness of a wall; but looking at the diagrams, and taking into consideration what he had seen of the work, there was a very good explanation. It struck him that on the Metropolitan railway, where property was so valuable, the batter which the late Mr. Brunel introduced of 1 in 5 would be extremely inconvenient; either the roadway would have to be narrowed, or a great deal more property would have to be taken, than would be otherwise necessary. No doubt the author would be able to say whether that had any influence in the carrying out of the work. Then with regard to the general question of the walls and their failure due to bad foundations, it struck him that the two things should be entirely separate; that the foundation should be treated as a foundation, and that having been made sufficiently strong, a properly proportioned wall should be placed upon it. He rather gathered from the paper that the two points had been taken as a whole, and that the author meant, "I have a bad foundation, and I will make the whole to stand." If that were so, it would have been better policy to have made a foundation of concrete, and then put a wall sufficiently strong. With regard to the question of theoretical calculation, there was a French formula which agreed remarkably with what might be considered the ordinary practice. He himself had put up a good many walls, not perhaps as distinct retaining walls, but in connection with bridges on 48 miles of the Mid Wales railway, and he had found practically that the $\frac{1}{4.5}$ of the height for the mean thickness stood perfectly well. In that case, it was to be borne in mind that there were two elements in addition to the theoretical calculation, namely, the projection of the footings where there was so much leverage, which was not taken into account in the calculation, and the weight of the earth resting on the projections or steppings at the back of the wall, Fig. 44. That, of course, aided the wall very materially; in fact, it might be called so much masonry saved. At all events, if merely the theoretical thickness of the wall was given, then, with the projections of the footings, and the weight of earth on the steppings, there was a very good margin of safety; and in that way the wall was erected with $\frac{1}{4.5}$, or 33 per cent. less than the dimension advocated by the author, and

Fig. 44



Scale 16 feet = 1 inch.

was a good and sufficient wall. One point with regard to walls was brought to his notice when in Canada, namely, the thickening of the top to resist frost. In ordinary circumstances the practice would be to put about 2 feet at the top, and then about 9 feet down a projection of 9 inches, and so on; but in Canada, on account of the penetration of the frost, it had been found necessary to make the top of the wall much thicker than was the practice in England.

Mr. H. Law desired to add his testimony to the great value of the facts laid before the Institution. It was upon such facts, the result of actual experience, that the most valuable data were formed. In the early part of the paper the author had pointed out that the formula usually adopted—Coulomb's—did not give the results which were obtained when loosely heaped materials were placed at the back of the wall; but a little consideration would show that that formula never was intended to apply to such cases. Coulomb's theorem distinctly took into account the adhesiveness or coherence of

the ground, and then determined, depending upon the line on which the ground separated, what the amount of pressure would be; and the value to the engineer was, that it determined what was the maximum which that pressure could be. Putting w=the weight of a cubic foot of the soil in lbs., h = the height of the wall in feet, r = the limiting angle of resistance of the soil, s = the angle between the line at which the soil separated and the horizontal, and P = the horizontal pressure in lbs. of the soil against the wall, then Coulomb's theorem might be thus expressed:

$$P=\frac{wh^2}{2}.\cot s.\tan(s-r).$$

Now in the case of a fluid, r, or the limiting angle of resistance, vanished, and consequently the result was that the co-tangent of s into the tangent of s became equal to unity, and

$$P=\frac{wh^2}{2}.$$

When the ground was sufficiently coherent to stand vertically, then the angle of separation being 90° the co-tangent of s became nothing, and the pressure became nothing. When the line of separation coincided with the limiting angle of resistance or r, that was to say, when there was a mass of earth sufficiently coherent not to break of itself, and lying upon a bed which happened to be at the limiting angle of resistance, the tendency of the earth to slide was exactly overcome by its friction, and r being equal to s, the tangent vanished, and P again became nothing. Now, between those two values there was a certain angle at which, if the ground separated, it would produce the maximum pressure, and that was given by Coulomb's theorem, which proved that when the line of separation bisected the angle made by the limiting angle of resistance with the vertical, then $\cot s=\tan(s-r)$, and

$$P=\frac{wh^2}{2}.\cot^2 s,$$

and the maximum pressure was obtained. The great value of the formula was to show, with a given weight of earth and a given limiting angle of resistance, what the maximum pressure was. It could not exceed the value expressed by making s half the angle between the limiting angle of resistance and the vertical. This formula could not be applied in the case of loose materials, as sand and gravel, because it was impossible for such materials to stand at any other than than their limiting angle of resistance; and under such circumstances there would be upon the wall only a comparatively small pressure, due to the unbalanced weight which remained from the efforts of the sand and the gravel to roll down upon itself. He wished to direct attention to one or two interesting exemplifications of excessive pressure which were met with in the works for the Thames tunnel. The Rotherhithe shaft, 50 feet in diameter, was built upon the surface and sunk by excavating beneath. That operation was successful until a depth of 40 feet was reached, and then, although the exterior surface had been made perfectly smooth by being rendered, it became earth-bound, and notwithstanding the earth was excavated to a depth of 2 feet round the whole margin, and 50,000 bricks were placed upon the top as a load, making the total weight 1,100 tons, and water was allowed to rise inside, the shaft refused to sink any farther. Now, taking the weight of the ground at 120 lbs. per cubic foot, which was about what it was on the average, and taking the coefficient of friction at 0.67, it would be found that a limiting angle of resistance of about 31° 15′, and a line of fracture of about 27° 30′, would show, by Coulomb's theorem, that the shaft would be bound, and therefore the practical result was quite in accordance with the pressure given by the formula. The author had mentioned a case of some heavy clay which had a pressure equivalent to a fluid pressure of 107 lbs., and if that clay was taken as having a limiting angle of resistance of about 5° or 1 in 10, and the weight was assumed to be 130 lbs. per cubic foot—which clay of that description might very well have—the formula would give 107 lbs. for the fluid pressure. He therefore thought these circumstances fully showed that where ground was coherent and adhesive, Coulomb's theorem applied. In the progress of the Thames tunnel there had been some remarkable cases of excessive pressure, where of course the weight of the water was superadded to that of the ground. He knew many instances of poling boards, 3 feet

in length, 6 inches wide, and 3 inches thick, supported by two poling screws bearing against cast-iron plates, being split lengthwise by the pressure of the earth against the outer surface.

Mr. E. A. BERNAYS said the inconsistencies alluded to in the paper tended to make it still more interesting than it otherwise would have been. There were few engineers who had carried out works, but were conscious of inconsistencies in their own practice and theories. The author had quoted M. Voisin Bey, the distinguished French engineer, as saying that he had rarely seen a long wall straight, and Mr. Bernays' experience fully confirmed that view. When it was straight the chances were there was a superabundance of material to keep it so. If it was run fine, as the calculations advised, the chances were 50 to 1 against having a straight wall. With regard to Mr. Brunel's section of wall, no doubt if it had a good foundation it was very strong for the material in it. It not only had a rising abutment, to bring the pressure down upon the foundation, but it had counterforts, which added greatly to the strength of the wall, although of late they had gone out of fashion. He considered it was nearer 10 feet at the base than 5 feet, as, if the counterforts were 10 feet apart, the wall was, practically, a solid wall. If made of concrete instead of brickwork, it would probably be found better to make it solid at once. The batter added considerably to the strength, but it was not without practical disadvantages. The greater the batter the greater the disadvantage. The tendency of the batter was to throw the side of a vessel farther away from the wall than need be, and to entail cranes with longer jibs, as well as the use of much larger fenders. Iron ships were now all covered with anti-fouling composition, which might easily be scraped off. With all its disadvantages he would rather have a smaller batter for practical purposes when ships were to lie alongside the wall. He had seen a wall of this section in Woolwich Dockyard (built, he believed, by Sir John Rennie, Past-President Inst. C.E.), partially pulled down and refaced by the late Mr. James Walker, Past-President Inst. C.E., for the purpose of deepening the dock. It was about 30 feet deep, and was increased to about 38 feet by putting a thin wall in front of it. In pulling down such walls he had always found that the backing in settling hung upon the set off, and he had seen holes under the backing large enough for a man to creep in. He would not say that they were objectionable in other respects, but he preferred a battered back to a retaining wall to square sets off. The author had alluded to a wall that he was building, and had characterised it as "exceptionably heavy." But for that expression he would have been quite content to sit still: he hoped to be able to show that the exceptionable heaviness was justified by the exceptional circumstances under which it was being built. He did not think much of experiments with peas and pea-gravel, and bits of board a foot square when he had to deal with big walls. The author stated (p. 47) that "experience has shown that a wall $\frac{1}{4}$ of the height in thickness, and flattering 1 inch or 2 inches per foot on the face, possesses sufficient stability when the backing and foundation are both favorable." Unfortunately for dock engineers it rarely happened that either the foundation or the backing was favorable, and it was still rarer to find both favorable. This fact made the inconsistencies that really showed the thoughtful way in which the paper had been written. There was no attempt to square theory with practice; but the author had candidly pointed out where theory broke down in referring to the retaining walls of the Metropolitan Railway, and at the approach to the Euston Station, and in other instances. He agreed with the author that the Sheerness river wall had perhaps a greater moment of stability than any other wall in the world. The section assumed that the pile foundation would stand, though he doubted its stability; but if it would stand, half the thickness of the wall would have been ample. He did not know sufficient of the nature of the subsoil at Sheerness to be able to decide the point. He had been told that in many cases the piles were 40 feet long; and a few years ago, when a new caisson was put in the basin at the yard, there was great fear lest it would come forward when the water was let out. That was merely an instance of the cases where provision must be made for very different calculations from those

which were set out in any table. He quite agreed with the author that no calculations would meet cases where the work was exceptionally difficult. In most instances, engineers were called upon to make docks and other great works in the worst kinds of soils, such as estuaries, beds of rivers, or in deep alluvial deposits. The reason that he strengthened the wall at Chatham was because the original design showed symptoms of weakness, and several of the walls yielded about 10 or 12 inches. He did not say that that was entirely the fault of the walls, because the foundation was far from satisfactory, and there was a decided forward movement of the piles; but it was evident that the wall, for the greater part of the area, was not at any rate too strong for the work. When, however, he came to the east end of the works, where he had to build a wall 1,050 feet long without a single break, and with 35 feet depth of soft mud to excavate through, it was absolutely necessary to strengthen the wall, and it was decided to build it entirely of concrete, in order to be able to give the additional strength without additional cost. He was asked some years ago what angle this mud would assume at rest, and the answer he gave was that it would not lie flat. The basin at Chatham was being built in an old arm of the river Medway, and the basin generally stood in the middle of the river bed. On each side of it the mud was 35 feet deep on the average, and in some cases the distance to be filled in with backing was 500 feet. The whole of that backing had to be laid on this sliding mud, which brought pressure on the wall in a way far beyond anything he had ever seen allowed for in any calculation. If he understood correctly, Mr Giles had thought it necessary to provide, not only for the backing, but for a pressure of water nearly as high as the water in the dock. He did not agree with Mr. Redman that it was possible to get the walls built up so as to prevent water percolating. At Chatham there was a standing level of the water in the district, and wherever excavations were made to that depth water was found. The bottom of the basin was 20 or 25 feet below that level, and the water exerted a pressure just as if there was an ocean of that depth behind it. Then it was sometimes necessary to put heavy buildings, as at the Victoria Dock Extension, where large sheds loaded with heavy goods were placed from 100 to 150 feet from the wall. No one would say that such sheds would not exercise a great pressure on the adjacent wall. He would be happy to show the author the wall at the Chatham Dockyard Extension, and abide by that gentleman's judgment, whether "the exceptionally heavy wall" was not necessary to meet the peculiar conditions of the case.

Mr. A. Giles, after what Mr. Bernays had said about the pressure of mud behind dock walls, thought he was quite justified in adhering to the assertion he made many years ago, that a dock wall ought to be strong enough to carry a head of water behind it equal to its height. He cordially joined in thanking the author for the paper, but he considered it would have been better described as "On the Stability of Retaining Walls." The author had given many examples of dock and retaining walls, but after throwing over the theoretical calculation as to the pressure of earth against a wall, he said that in ninety-nine cases out of a hundred walls failed from faulty foundations, and not from want of strength in themselves. The various diagrams afforded rather congratulatory evidence of his own theory, that practically all the thick walls had stood, and most of the thin walls had given way. Referring to the old Southampton dock wall, mentioned as having been built 40 years ago, that had only a thickness of 32 per cent. at the base, but with the counterforts it was 35 per cent. That wall had been pushed forward, but it never came down; but it was saved by taking out the wet soil at the top and covering the top by a timber platform. Another wall which he had built had been referred to. That had a thickness of 45 per cent. at the base, and an average thickness of 41 per cent. Surely that wall ought to be strong enough to resist not only the pressure of water behind it, but even the pressure of mud that would not stand at a level. It had not stood without moving—not from any want of strength in the wall, but simply from the want of adhesion in the foundation. At Whitehaven the thickness of the wall was 37 per cent. at the base, and the mean thickness was 31

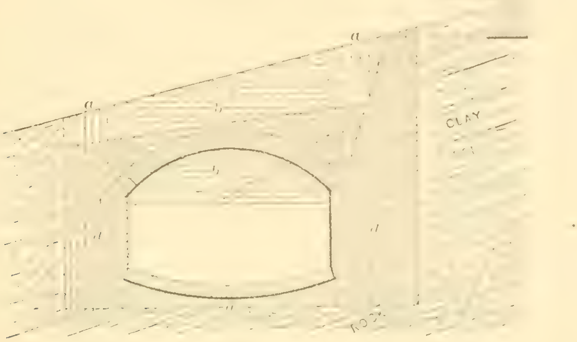
per cent., and it had stood. At Avonmouth these values were respectively 59 per cent. and 42 per cent. There was a very fine example at Carlingford of a wall with the base only 32 per cent. thick, and a mean thickness of 24 per cent.; but what could be said about a wall at Sheerness with a height of 40 feet and a base of 43 feet? It was stated that that wall had not moved, and Mr. Bernays had contended that it ought not to move; but he did not think any engineer of the present day would dare to design, or contemplate building, a wall of that character, because a wall of similar height in ordinary ground could be built for £60 a yard, while that wall would cost £300 a yard. In many instances it was not the inherent weakness of the walls that caused them to fall, but the slip at the bottom, and that was shown in Fig. 17 by the necessity which arose for thickening the wall so as to make the strength as 62 to 24. After all, the wall required still further strengthening by putting buttresses in front of it. The conviction he had arrived at was, that it was not generally the fault of the wall that caused the failure; but the fault of the foundation—not only that the foundation was not wide enough to give sufficient hold on the ground, but that there was not sufficient footing in front of the wall to enable the soil upon which the wall rested to sustain the weight. It was the same as if a cliff, 30 or 40 feet high, were put on tender soil. The soil would not be strong enough to bear it, and consequently the edge of the cliff would settle into the soil, the soil would burst up in front, and the pressure from behind would then make itself felt. He had seen that process take place in a wall which he had constructed, and it was only saved by putting buttresses in front of the footings. Something had been said in the paper about allowing a margin for contingencies. In that matter every engineer must decide for himself; but he thought that from $\frac{1}{4}$ to $\frac{1}{2}$ was rather a large margin, and he would suggest that the thickness of a retaining wall $\frac{1}{3}$ of the height would be, in nine cases out of ten, ample to resist the backward pressure; but he would insist upon having a large buttress in front of the foundation, carried down as deep as the lowest foundations of the wall. He was at a loss to imagine what the extraordinary projection in front of the wall at Marseilles (Fig. 25) meant. It might be that it was intended to hold the bottom down; and it was in that direction he would recommend retaining walls should be strengthened. A remark had been made about the necessity of having the upper part of dock walls nearly perpendicular, because of the friction of ships rubbing against them, and the inconvenience of ships lying at some distance from the quay at the coping level. That was perfectly true, and he believed it had been a common practice, in designing walls where there was a curved batter, to make the center of the curve level with the coping, by which a certain depth of almost perpendicular work was obtained from the coping level. He believed that was the correct principle; but he would urge particularly that, in making dock walls, the foundation should be much wider than they were in general, and that the bulk of the buttress should be in front of the face of the wall, and not behind. In all walls the excavation at the bottom should be carried down perpendicularly, with as little disturbance of the soil as possible; because in excavating the work, it was better to fill up the void so made, that there should be no tendency to slip after the wall was put in. There was another point which he thought was not sufficiently considered by engineers in designing dock walls. They were apt, when the excavation had been carried out, to think that they had got a good foundation; but he cordially agreed with the author when he used the word "lubricating." Notwithstanding what Mr. Redman had said, he did not think it was possible to keep water from getting behind a dock wall: he believed there was a point at which water would always be found: it would get up from the bottom or through the wall somewhere; and that being so, he thought that all the soil upon which the wall stood must be soddened and lubricated to a certain extent. He knew of instances where walls had stood for many years; but all at once the moment of lubrication had arrived, and they slipped in. He could only account for it by supposing that there was a tendency on the part of walls to get surrounded with water, by which they became of less specific gravity, or that the soil got satu-

rated, and therefore less able to bear the load put upon it. He would therefore urge upon all his professional brethren who had the conduct of dock works to look particularly to the front of the walls to ensure their stability.

Mr. W. R. Bousfield desired to make one or two remarks, from the theoretical standpoint which the author had deprecated. He referred to a point in which theory and practice would agree, viz., as to the effect of water behind a retaining wall. If there was an interstice of even an inch the effect on the wall would be exactly the same as if the whole ocean were behind it; therefore, a dock wall should be made to withstand a pressure equal to the hydrostatic pressure due to a head of water of the height of the wall. He wished to ask if the author could explain, somewhat more at length, the effect of lateral pressure in General Burgoyne's experiments, for he did not think the remarks were quite sound. If the lateral pressure of the ground, consisting, say, of loose rubble, was greater than the hydrostatic pressure, the fact of water being admitted would not make the slightest difference, because the water pressed equally on the earth and on the wall in opposite directions, so that the earth would be kept back by the pressure, and the difference between the lateral pressure and the hydrostatic pressure would be exerted by the earth on the wall. The only effect would be in the distribution of the pressure, which instead of being taken by the points of stone alone, would be distributed by the water over the whole wall. If the lateral pressure of the soil was less than the hydrostatic pressure, then of course, if water was admitted behind, it would exert upon the soil a force greater than the pressure of the soil on the wall; therefore, supposing the soil were rigid, the lateral pressure of the soil would be kept entirely off the wall. Of course, in practice, there were many points at which the pressure was excessive, so that, on the whole, the maximum pressure to be provided for would generally be rather more than the hydrostatic pressure.

Mr. E. Benedict described a retaining wall (Fig. 45) lately put up at Ryde. The ground was sidelong and at the foot of a clay hill, the strata dipping towards the work, and with a heavy building close to it. By cutting a trench and filling it as soon as possible with solid concrete in Portland cement carried up to the surface, the clay, which weathered rapidly when exposed to the air, was covered without delay, the concrete became agglomerated with the clay at the back, and did not allow any percolation of water. The excavation in front of the wall then proceeded without any movement of the ground occurring, and he thought that none would take place. Eventually a covered way was formed on the lower side of the wall, the arch of which was designed so as to form a continuous lying buttress.

Fig. 45



Mr. B. Baker, in reply, observed that he agreed, to some extent, with almost everything that had been said in the discussion, and he considered that the criticism had been very fair. He was glad indeed that he had elicited so many valu-

able opinions on the subject. Mr. Airy spoke about the difference in the cohesion of different clays. He had noticed the same thing himself, not merely in different clays but in the same clay. A railway cutting often refused to stand at a less slope than 4 to 1, and yet the same clay, after being tempered a little, might be found in an adjoining brick kiln standing with a vertical face. He had nothing to say with regard to Mr. Vernon Harcourt's comments, except that he agreed with almost everything that gentleman had said. Mr. Barry had made some sensible remarks about the advantage of using struts to retaining walls, and he thought it would be a good thing, in many cases, to imitate the old architects of cathedrals, and substitute flying buttresses for a heavy mass of materials. Some time ago he designed some very cheap sheds upon that principle, in which the roofs were light concrete arches supported by flying buttresses. Mr. Barry had referred to the cracks at the angles of some of the piers of the Metropolitan District railway retaining walls. He was satisfied that these did not arise from pressure, but from chemical action, because they occurred only in the case of certain bricks, and he knew where the bricks came from, and had every reason to mistrust them. He had sometimes found scaling occur all over the face of a wall, though of course the angle was always the weakest point, and nature always tried to round off an angle, as might be seen in Cleopatra's Needle, where there was no square angle. Mr. Lewis had described a wall designed by the late Mr. Brunel, but he did not approve of it, for reasons that had been set forth by Mr. Bernays. He himself had found exactly the same thing, namely, that in pulling down work where there had been the slightest settlement, the earth at the back did not rest on the offsets, indeed, not infrequently, a man could push in his arm between the offset and the filling. It was therefore idle to maintain, as Professor Rankine and others did, that the earthwork resting on the offset was as good as so much masonry. There was no economy in putting in the offsets, and he attributed the stability of apparently light walls so constructed to the pressure of the counterforts and the good quality of the backing. Mr. Redman had directed attention to the fact that there was an increased thrust when the ground at the back was sloping. No doubt that was so; and a case of that sort was referred to in the discussion on Mr. Constable's paper at the American Society of Engineers, where the ground at the back was sloping rock. When the wall was first put up and the backing was filled in, the whole mass came forward in consequence of the wedge of earth sliding down the surface of the rock. The masonry was pulled down, the rock cut in steps, and the wall rebuilt of the same thickness. Pig iron to the extent of 55 tons to the lineal foot was then placed behind the wall, and it stood perfectly well, though the thickness was less than 30 per cent. of the height. That was sufficient evidence of the importance of stepping the ground at the back. Mr. Atkinson said he thought it would be better to make the foundation satifactory first and then to build a thin wall on the top of it. At page 43 of the paper that point was alluded to and the answer given. Mr Law had submitted a formula, and drawn deductions from it, which he could not follow; but it seemed to him that the contention was that a loose material exerted less thrust on the wall than a more compact material, and that Coulomb's theory was not applicable to loose soil. He did not agree with that view in theory, and Lieutenant Hope's experiments showed that that was not so in practice, at least on a small scale. Lieutenant Hope placed a board behind the pressure board at such an angle as to include Coulomb's wedge of maximum thrust between the two boards, and found that the lateral pressure was quite as much when the board was at the slope of repose, $1\frac{1}{2}$ to 1, as when it was at half the angle. There was hardly any difference whether the board was horizontal or at a slope of $\frac{1}{2}$ to 1, or at any intermediate slope. Then it had been remarked with regard to one of his examples, in which the stability of the wall was equal to the fluid pressure of 107 lbs. per cubic foot, that theory would indicate the pressure to be about that amount; but a statement in the paper did not seem to have been noticed, that the wall never had that pressure on it, but failed by sliding forward. Of course it might have slid

forward with a pressure of 40 lbs. per cubic foot, but since the struts had been put in, there was not the slightest indication of movement, and therefore the moment of stability could not have been deficient. Mr. Bernays seemed to imagine that the expression "excessively heavy" reflected on the design of the Chatham dock wall, but the intention was the reverse. He entirely approved of it, and considered that it was a well-designed and creditable engineering work in every respect. It was one that he should imitate. His contention throughout the paper was that formulæ did not apply to such works, and although he began the paper with a diagram he set it up merely in order to knock it over. Mr. Giles considered that instead of the limits of $\frac{1}{4}$ to $\frac{1}{2}$ of the height for the thickness of a retaining wall, $\frac{1}{3}$ should be the limit with a buttress in front of the toe; but he did not think that that was the practice which had been followed in the Southampton Dock Extension, where the limit, he believed, was nearer $\frac{1}{2}$ than $\frac{1}{3}$—45 per cent. The curious slope projection in Fig. 25 was really an apron to protect the foundation, which was of clay. The clay was very hard when laid bare, and a sort of shield was put there to prevent its softening. He believed the same thing had been recommended by a committee of engineers in the case of the Belfast dock, where the wall failed; but it was applied too late, or the conditions were different, because the wall came forward notwithstanding.

ON THE REVELATIONS OF SANITARY SCIENCE.

From "The Builder."

This was the title of the paper read by Mr. Edward C. Robins, at Eastbourne, last week, on the occasion of the Sanitary Exhibition there already referred to. After alluding to the various papers recently read, and the discussions of the subject which have taken place with hopeful results, Mr. Robins made some useful general observations on the importance of sanitary knowledge, and on the advantages which had already become apparent from the spread of it, and thus proceeded:

Let us now briefly refer to some of the more important principles which sanitary science teaches, premising that there are two distinct systems of sewer-construction, broadly distinguished by the phrases *sewers of deposit* and *sewers of suspension*, both having reference to the water carriage of excrementitious matter. The *former* is adopted in many great towns, and does not necessarily provide for the immediate removal of the soil from the houses except in times of storm or very wet weather. At other times a system of flushing more or less intermittent is involved, owing to the absence of sufficient water for the carriage of the soil accumulations and refuse. The *latter* is adopted in some provincial towns, as Croydon, and requires the removal of the soil at once at all times of the year, or at least before the solid matters in suspension have had time to enter into that putrid state when sewage gases of a most deleterious character are generated within the sewer. Obviously the *former* system is one which, by providing for occasional storm-waters or heavy rains, over a large surface of land, as well as the ordinary house-sewage, necessitates the construction of vast cavernous sewers, which in dry weather (from the absence of adequate rainfall and sufficient flushing arrangements) constitute sewers of deposit, the emanations from which are often so deadly (owing to the insufficiency of ventilation) that disease and death are pent up within them, ready to find a way through every aperture into the dwellings of the rich and poor alike, so that the lives of the prince and the peasant are equally endangered by living in houses or hovels, whose drains are in direct communication with the public sewer, unless those precautions are taken which it is the business of sanitary science to discover and to enforce. The *latter* system is one which provides a sep-

arate sewer for storm-waters, or leaves them to care themselves and find their own way into the rivers and the sea, and thus necessitates the conduct of the house-drainage only in comparatively small pipes, the smallness of the bore concentrating the stream of water which carries with it the soil held in suspension along the narrow channel provided.

Mr. Chadwick, in his recent pamphlet entitled "Circulation or Stagnation," quotes the address of Mr. F. O. Ward, at the Brussels Congress in 1856, on a system of sewerage involving the utilization of the sewage by irrigation, briefly summarised in the following description of a sanitary Arcadia:

"The water which falls on the hills in a state of purity undergoes a natural process of filtration through sand, enters the rural collecting pipes, and passing through the aqueduct to the metropolitan distributing-pipes, finds its way to every story of every house in the town; when, again, after having supplied the wants of the inhabitants, it runs off enriched with fertilizing matter, which it carries away before allowing it time to ferment. This manure, driven along irrigation pipes, is deposited in the soil, leaving the water to pass into the drainage pipes, and flow on to the rivers. The rivers conduct it to the ocean, whence it rises as vapor under the heat of the sun, to re-descend as rain on the hills, enters again the collection-pipes, and recommences its vast and useful course of circulation."

In opening the discussion which followed the reading of my paper at the Royal Institute of British Architects, from which I have made the foregoing extracts, Dr. Corfield remarked: "Mr. Robins has said that civil architecture can never be divorced from the experience of sanitary science. I would go farther than that, and would say, that if it were not for the experiments that have been made by scientific men, no alteration in principle would be carried out, not only in architecture, but in everything else. If it had not been for the chemist Pasteur, for instance, all the vine-growers in the world would never have discovered the cause of the destruction of their vines; the fowl-keepers would never have discovered the reason for the loss of hundreds of thousands of their poultry by hicken-cholera; and the prevention of the silk-worm disease would have remained an unknown problem. And," he asked, "what is it that has caused us to think so much of *sewer-air*? There is one reason, and only one, and that is, that it has been shown by scientific experiment—by the experiments of sanitary science—that enteric or typhoid fever is produced by a constituent of that air; yet the public mind was not aroused to the necessity of preventive measures until one or two members of the Royal family suffered from that disease."

Sanitary science has revealed to us, by the positive experiments of its professors, the necessity of devising means for the ventilation or disconnection of the house-drains from the main town sewers, be cause it has been shown that foul gases will pass through water, that on one side of the water in a trap they are absorbed, and on the other side they are given out, and that this process goes on continually. And if this is the case, even when a house-drain is siphoned off by a water-trap, what must be the condition of those house-drains which are not trapped at all, but the sewer-air is laid on by those to the interior of the dwelling through any untrapped sink or closet, or leaky joint, and with the use of disinfectants serves only to conceal from observation, and to hinder the perception of the cause?

Dr. Frankland's experiments have proved that when water contains foul matter decomposition takes place in the water, and the surrounding air is contaminated by the bubbles of gas generated, releasing the infectious particles along with it, thus showing the desirability of intercepting manholes to house-drains, even where water-traps exist, and demonstrating the fatal consequences likely to ensue when neither water-traps nor manholes exist, which, nevertheless, is still the case in the great majority of dwelling-houses in the land.

Thus, through thn revelations of sanitary science, mechanical appliances have been devised like those exhibited upon the walls, by the aid of which it is now quite possible, as Dr. Corfield has proved, to put a house into such a condition of safety that we can say, with perfect certainty, that if typhoid poison is in the main sewer, it will not get into the house; and, fur-

ther, that if typhoid fever is taken into the house, when such preventive measures are taken it will *not spread*.

Sanitary science having first revealed the ready absorption by water of bad gases, as already mentioned, mechanical means have been devised by practical sanitarians to prevent the *drinking-water* in our cisterns and wells from becoming contaminated. It is common to find wells situated so near to cesspools that the water of the former is rendered impure and poisonous by the percolations from the latter. It is common to find the only supply-cisterns fixed over the closets for the convenience of having service-boxes in the same for their supply; and the trumpet overflow waste-pipe fixed in direct communication with the pan-closet or the soil-pipe.

Your exhibition teems with devices for overcoming these evils. Pan-closets are condemned, valves only are admissible; service-boxes are discarded; disconnecting waste-preventers are provided; the wastes empty into the open-air, and, as a rule, a separate cistern for drinking-water is provided.

I have suspended on the walls the illustrations of Mr. Pridgdin Teale's book, entitled "Dangers to Health," which will both amuse and instruct you; indeed, I know no better medium for opening the eyes of the popular mind to a right understanding of what to fear, and how to defend yourselves, than that very interesting volume.

Dr. De Chaumont has said that, parallel with the progress of medicine and the collateral sciences, advances have been made in sanitary science which amount to important revelations, so that it has become possible to lay down certain principles which, as we have seen, are capable of practical application to the great advantage of us all. Thus the dwelling in marshy districts has been proved, by incontrovertible evidence, to be usually followed by attacks of ague and fever of various kinds. That destitution and crowding give rise to typhus. That the withdrawal of vegetable diet produces scurvy. That smallpox, measles, and scarlet fever are communicated by contact to otherwise healthy persons. And by equally strong evidence, though not so generally accepted, acknowledged and acted upon, sanitary science reveals to us that, out of the 700,000 deaths that take place in one year in the United Kingdom, no less than one-third, or some 240,000 deaths have been traced to those particular diseases which are liable to be favored or propagated by neglected house sanitation. In fact the highest medical and sanitary authorities have decided that, by good sanitary appliances and surroundings, resulting in the maintenance of the purity of the air and water within and around our dwellings, typhoid fever, diphtheria, sore throat, and cholera might be rendered exceptional diseases, instead of being, as they now are, the fruitful causes of illness and death to the alarming extent these statistics attest.

Let us proceed to notice some further revelations of sanitary science. We have glanced at the cause and cure of defective house-drainage and water supply, we will now refer to the *nature of the sub-soil*. As I have said elsewhere, a damp site makes a damp house, not only by the surface dampness of the surrounding ground, but, as Professor Kerr has also pointed out, by the ground air, which forces the moisture under and into the house, drawn forward by the very means adopted for warming the interior, which by lightening the weight of the internal air, makes a free passage for the heavier cold damp ground-air in the direction of the least resistance.

There are two general divisions in classifying soils—the pervious and the impervious. *Pervious* soils are those like gravel, sand, and soft limestones, which allow of the free passage of water through them, and if there is nothing to obstruct its free passage, and the level of the water in the ground is sufficiently deep, the upper surface upon which the house is built is always dry and healthy. If, however, the gravel has no deep outlet for the water which passes into it, owing to its being situated in a basin of impervious soil, so that the level of the water in the soil is brought very near the surface, then it is necessary to find an outlet for the accumulated water by artificial means, called land drainage.

Impervious soils are those chiefly composed of various clays, which do not allow the waters to sink into their depths, but only suffer it to flow over their surface, and consequently the garden soil

gets super-saturated, and if the land is level the water is longer in getting away, and the evaporation of the moisture in and upon the soil produces a humid, damp atmosphere, very injurious to health, and requiring very careful surface drainage to overcome.

The public roads, forecourts and areas of town houses are usually well drained, so that less evil comes from this source in the front of such houses, as a rule; but the back gardens are commonly neglected, and the basements suffer in proportion. It is obviously important to look to the surface and subsoil drainage of the site of the house you inhabit. But this is not all. Suburban villas are not always built on natural soils at all. The brickmaker has sometimes preceded the builder in impervious soils, and the gravel and the sand merchant in pervious soils; and to bring the land to one uniform level, the well-known notice board has appeared, inscribed "Rubbish may be shot here," which, interpreted, means, "the seeds of disease may be sown here." The foregoing revelations of sanitary science have led me to cover the basement floor of my own and of my clients' houses with a solid and practically impervious flooring. Let me give you the prescription. Provide deal, pitch pine, oak or other wood blocks, 7 in. by 3½ in. by 2 in. thick. Burnettise them, and lay them in herring-bone or other patterns, bedded in gauged lime-and-hair mortar, after first dipping each block half its depth into hot pitch, the whole resting on a solid foundation of ground lime or cement concrete, averaging 6 in. thick. The interstices of the blocks to be filled in with Portland cement powder swept over them, the surface to be then washed with water, which, setting the cement in the joints, makes a permanent floor, which may be polished, or ornamented by Mr. Webb's process exhibited in the Eastbourne Exhibition.

So far we have been considering the effect, upon the health of the community, of bad drainage and water supply, and damp subsoils. But when we have succeeded in ventilating our drains and water, and subsoils *out* of our houses instead of *into* them, we have next to consider how to *maintain the purity of the air of the rooms we inhabit and defile* with our own breathing, our house warming and lighting, and cooking, etc. In this matter also sanitary science has made many revelations of more or less gravity. The late Dr. Parkes has shown in great detail the various sources of impurity to which the air of enclosed spaces is subject, and the particular diseases to which such impurities give rise under the title of "Ventilation"—a term which he restricts "to the removal by a stream of pure air, of the pulmonary and cutaneous exhalations of men, and of the products of the combustion of lights in ordinary dwellings; to which must be added, in hospitals, the additional effluvia which proceed from the persons and discharges of the sick. All other causes of impurity of air ought to be excluded by cleanliness, proper removal of solid and fluid excreta, and attention to the conditions of surrounding dwellings."

To expound the revelations of sanitary science by which the above impurities are detected, measured, and overcome, is my next intention; and, having regard to the mixed nature of my audience, I will do so in as popular a manner as possible.

It is usual to measure the impurity in the atmosphere by the proportion of carbonic acid it contains—not because this is the only or even the chief cause of its unhealthiness, but because the presence of carbonic acid is indicative of the proportional existence of other impurities, viz., foul organic matter and moisture, and also because the amount of carbonic acid can be accurately measured, and therefore may be usefully taken as an index of impurity generally.

The average amount of carbonic acid in the air outside of the house is four parts in 10,000 parts; when it reaches six parts in 10,000 inside, the room begins to be stuffy. Dr. De Chaumont has shown that about 3,000 cubic feet of fresh air per person per hour are necessary to preserve the air quite fresh; practically, however, no more than 750 cubic feet per person per hour is attainable in this country without producing draughts.

As Dr. Corfield observes, the air in our houses is rendered impure in various ways, but chiefly by our respiration, and by the products of combustion that are allowed to escape into it from lights and fires. Thus the air that we expire con-

tains a certain quantity of foul or putrescent organic matter. It is charged with moisture, and contains about five per cent. less oxygen, and nearly five per cent. more carbonic acid, than the air we inspire. Add to this that every foot of gas consumed is equal to the addition of one person's expiration, and the need of changing the air is quite obvious. This change of air can only be effected by the admission of fresh air and the concurrent abstraction of foul air. It is not enough to provide for the extraction of air without providing for its incoming, because the effort of natural forces seeking equilibrium will cause the air to be drawn through every crevice in the doors and windows, and even through solid walls and floor, creating currents of air *en route* to the motive power; viz., the partial vacuum which the fire in the grate produces. Neither is it sufficient to provide for the admission of air if there are no means of outlet; and if the chimney-flue is closed it will not enter of itself at all, but will require to be forced into the room, by which process the occupants of the apartment will feel no more delightful sensation than is experienced by a descent in the diving-bell at the Polytecnic.

In ordinary houses, the chimney is a sufficient ventilator when associated with a means of feeding the chimney with a supply of air, to prevent its feeding itself by drawing from every crevice as aforementioned. To feed the fire directly, however, would probably prevent draughts, but it would decrease the warmth and leave the room unrefreshed by the change of fresh air for expired air. Consequently it is obviously desirable to introduce the air in such a way that it may do all the good it can before it reaches the fire and is swallowed up by the chimney current.

Now, it has been proved by experiment that the ordinary current up the flue of a sittingroom fire-place is at the rate of from three to six cubic feet per second, or 300 cubic feet per minute, or 18,000 cubic feet per hour. Consequently, allowing 1,000 cubic feet of air per hour as necessary to be extracted for each occupant of any chamber, obviously one sitting-room where the fireplace flue is a sufficient extractor for eighteen persons; if 3,000 cubic feet per hour be insisted on, as recommended by Dr. De Chaumont, then six persons are efficiently provided for by this means, which is all-sufficient for practical purposes in dwelling-houses, except in the reception-rooms on party nights, when a much larger volume of expired air will be required to be extracted, to make way for the equivalent of fresh air which it is necessary to introduce to keep up the interchange and to maintain the purity of the air generally. In winter this fresh air can be warmed in its passage.

The foregoing principles underlie the best of the mechanical appliances constructed for the ventilation of dwelling-houses. And proceeding upon these lines, Mr. Tobin has credit of reviving an old principle laid down by Mr. Whitehurst, F.R.S., and published in 1794, and of putting it into practical use most successfully at the Ophthalmic Ward of St. George's Hospital, which is a room about 20 ft. square by 14 ft. high. Mr. Tobin closed all extract ventilators except the open fireplace, which is necessary to keep going, winter and summer, and day and night, to maintain the velocity of the upward current in the chimney, which was thus retained as the only and sufficient extractor. He next provided some eight or ten semi-circular zinc shafts, about 5 in. or 6 in diameter, and 4 ft. or 5 ft. high, and fixed them at the four corners of the room, and equidistantly between them. These shafts are connected at the foot with horizontal channels leading through the thickness of the walls to the outer air, and form the fresh air inlets,—one set of shafts being in communication with the channels leading to the outer wall gratings fixed on one side of the building, and one set of shafts communicating in a similar manner to gratings on the opposite side of the building. This was an afterthought, for when all the shafts communicated with the outer walls on one side of the building only, the room was either supplied with too little or too much air, just as the direction of the wind might happen to be towards or away from the said inlet gratings. In this way the fresh air was introduced and the foul air extracted. No draught was felt by the patients, much less by myself and other professional visitors who congregated round the fire expecting such a result. In fact, the prophecy of Mr. Whitehurst,

delivered a hundred years before, was fulfilled thus: Given, an air-duct about 3 ft. or 4 ft. long, and 5 in. or 6 in. diameter, fixed in either corner of the room most remote from the fire, and communicating with the external air, the incoming air will rise in a perpendicular direction to the ceiling, and being gradually diffused will soon acquire the temperature of the room. No person will be sensible of it, and the flame of a candle will not be in the least disturbed by it.

The Sanitary Engineering and Ventilating Company have done their best to improve upon this suggestion, and at the International Medical and Sanitary Exhibitions at South Kensington, their various models were exhibited, showing how the blacks and dust may be intercepted in the passage of the outer air into the interior of the dwelling, and your own exhibition also furnishes examples.

The introduction of fresh air is specially provided for in a variety of stove-grates, and notably by Boyd's Hygiastic School Board stove; under the iron hearth, and through the gills at the back of the grate the fresh air passes, and is warmed in winter before it enters the room through the gratings in front of the stove, which are proportioned to the size of the room in which they are fixed for both warming and ventilating purposes.

Mr. Boyd does not consider the chimney a sufficient extractor, but always recommends extract ventilators to be used with his stoves, fixed at the foot of an air flue built in the upper part of the wall opposite the stove, with not only a means of opening and cleansing the same, but also of heating the extract flue by a Bunsen gas-burner, as a means of rarefying the air in the shaft, and increasing the upward draught. If the objection is made that by forming extract flues you will materially increase the cost of the building by doubling the width of the chimney breasts and stacks, I answer "No! If you are willing to do as I did, thirty years ago, at Mr. Boyd's suggestion, instead of making the withe or division between the flues of solid half-brickwork, make a hollow flue by the introduction of cast-iron flue plates the thickness of a slate, leaving a clear 4 in. by 9 in. or 14 in., as the case may be, for a ventilating flue warmed on either side by the smoke-flues between which it is situated, occupying no more space than the ordinary flue-withe, and delivering into the open air 3 ft. below the smoke-flues through louvered openings.

But sanitary science teaches us to regard ventilation as something more than this. It has revealed to us that ventilation cannot be rightly studied and practised without due consideration of the mode of heating and lighting intended to be adopted in the room to be ventilated. Indeed, the temperature of the air within a room and without it, being different in density, in proportion that either is hotter or colder than the other, is one cause of the pressure of one atmosphere against another in search of that equilibrium which nature is ever seeking, and never finding for any length of time together. The whistling wind rustling through the woods and forests bloweth where it listeth; we hear the sound of it, but cannot tell precisely whence it cometh or whither it goeth, until we have traced to its source the provocative cause of its movement, which will be found to arise from the variations in humidity, temperature, and consequent density and pressure of the heavier against the lighter and brighter atmospheres, with which the former impinges upon the latter. Thus the draughts in a room are the result of the cold air of the street or passage in its struggle to get to the warm air of the room, and particularly that part of it from which the heat is generated and projected.

When two rooms are of the same temperature, the air is stagnant; that is to say, no movement of the air from one to the other will take place by the opening of a means of communication between them. It is obvious, therefore, that if the whole of the interior of a house were equally warmed without the provision of inlets for fresh and outlets for foul air, there would be no change of air from one part of the house to another. But each room might be separately lighted, warmed and ventilated by inlets and outlets, and yet the same temperature might be maintained, but with this difference, that there would be no stagnation, but pure fresh air, warmed as it entered for free inspiration, and withdrawn as by expiration or combustion it became impure. In the ventila-

tion and warming of the house, the hall and staircase should not be forgotten. The best salvation from the wasteful consumption of fuel is the withdrawal of the cause of the draughtiness of rooms when the door is opened, arising from the difference in temperature between the sitting-room and the hall, by the introduction of a good hall fire or other system of warming the entrance hall and staircase.

With reference to the lighting of rooms, of course the softest and most agreeable method is by wax candles, but the cheapness and brilliancy of gas, and its easy application has led to its general adoption, regardless of the sanitary consequences. For as Dr. Corfield observes in his Cantor lectures, "Candles, lamps, and gas all help to render the air im pure."

"It is calculated that two sperm candles, or one good oil lamp, render the air about as impure as one man's respiration does, whereas one gas burner will consume as much oxygen and give out as much carbonic acid as five or six men, or even more. This is why it is commonly considered that gas is more injurious than lamps and candles, and so it is, when the quantities of light are not compared; but with the same quantity of light, gas renders the air of a room less impure than either lamps or candles." Common sense at once suggests that the products of combustion should be carried away, and the heat generated by the process should be utilized to expedite its removal, and several manufacturers have turned their attention to this desirable end, and at the International Medical and Sanitary Exhibition, and at your own exhibition in this town of Eastbourne, examples may be found of many means to attain this end. Strode's sun-burners, Benham's globe light, Faraday's pendants, and many more appliances, all seek to give practical application to the principles above referred to. But we are fast arriving at the best solution of this difficulty through the agency of electricity. The sanitary side of this new lighting power is to us the most interesting. By the Lane-Fox and Swan incandescent lights, unequaled brilliancy, steadiness, and continuity of light are capable of being maintained, and this all produced within a vacuum formed within the globe of glass in which the light is produced: and consequently, by the use of these lights (which are becoming more common every day and will soon supersede gas altogether), no heat is generated, no dirt is caused, and no products of combustion mingle with the air of the room, from which no provision needs to be made in its ventilation for this system of lighting, which, as hereinbefore explained, is so necessary in the case of other lights.

This brief review of the revelations of Sanitary Science would not be complete without a few words on heating.

The natural process by which the temperature of the air is raised is either by radiation or conduction. Conduction, or rather conducted heat, is the warmth given off to the air by heated surfaces brought into immediate contact therewith. Such heat in the ordinary fireplace is carried up the chimney, and the systems in use for generating it are known as hot air stoves or flues, hot water carried in cast iron pipes at low pressure, or in wrought iron pipes at high pressure, and steam pipe apparatus.

Radiated heat is like that of the sun, which passes through the air as light without heating it, into the earth or any intervening substance, from which the heat is given off gradually to the atmosphere, creating the difference between sun and shade temperature. Thus it is that the conducted heat of an open fire goes up the chimney, as I have said, and about a sixth part only is radiated into the room, passing through the air without sensibly heating it, but warming the first obstacle to its progress, such as the inclosing walls and furniture, by which the radiated heat is given off to the air of the room, raising its temperature as required. It cannot be called an economical mode of heating, being but one-sixth of the means to the end; but it is the most enjoyable and the most healthy. All the products of combustion pass up the chimney, and draw after them the impurities and denser air of the room lying lowest, while the vivifying rays of the crackling fire heat without scorching the surfaces that warm the air of the room insensibly.

The primary but not the exclusive object in the improvement of an open fire stove must obviously be the increase of

its radiating power, by reflection from heated polished surfaces in close contact with the fire, and this is done by many of the best stoves—one of the latest of which is Messrs. Comyn, Ching & Co.'s new stove called "The Paramount." In this case the fire basket or grate is quite disconnected from the brickwork surrounding it, and equally so from the metal case, excepting at the point of contact with the bracket which sustains the circular grate. Thus the fire is enabled to radiate as from a center all round. The rays of heat emitted from the back and sides of the fire basket, impinging on the metal reflector of the back and sides, are reflected forward into the room and utilized, instead of being lost as before.

The secondary object, economy in fuel, is attained by the first, and by bringing in conducted heat from chambers provided at the back of the grate; and the third is the consumption of smoke. This has occupied a great deal of attention of late, with the object of purifying the air of blacks and the reduction of London fogs. An exhibition of stoves designed with this object will take place in London in October, and we shall soon see with what result.

In the meantime, the "Wonderful Grate," exhibited by Messrs. Smith & Co., at the London Sanitary Exhibition, accomplishes a great deal in this direction. It is an open fire grate, and yet consumes its own smoke. It burns anthracite coal. It is fed with fuel in the morning, and needs no attention till night, until the fuel is consumed. It requires no stoking, yet has always a clear, bright, red fire, the radiating power of which is considerable. Then there is Dr. Siemens' grate, which is an attempt to combine gas with anthracite coal, and a host of others.

The history of the heating and ventilation of the British House of Commons, both old and new, is perhaps as instructive a lesson in this branch of sanitary science as any which could be named. Sir Christopher Wren, Captain Cook, Sir Humphrey Davy, the Marquis de Chabannes, and many others tried their hand at the old building. Dr. Reid, Mr. Gurney and the present Dr. Percy, have had their way with the new. However, it is not my intention to refer to public buildings now, but only to draw attention to the importance of the principles laid down by sanitary science which are applicable to all householders, and the revelations of which I have now traced as they have influenced house drainage and the ventilation of the same, house warming and lighting, and the ventilation of the rooms in which we live and move and have our being.

If I have made no new revelations, I have at least endeavored to popularize the old, and I think we may look forward with confidence, as the result of such exhibitions as that which you have inaugurated in this town that their need will become less and less as time advances, knowledge increases, and the evidence of the value of these revelations accumulates. It is a work of "sweetness and light." It aims to realize that which hitherto has existed more in the imagination of the poet than in fact:

"Home, *sweet* home."

A NOTE ON CURRENT DEPHOSPHORIZING PRACTICE.*

By SYDNEY GILCHRIST THOMAS and PERCY CARLYLE GILCHRIST.

From "Iron."

It being now just three years since the first detailed communication on the subject of the technical possibility of a complete and direct dephosphorization being effected in the Bessemer and Siemens processes was offered to the Institute, and nearly two years since the first working on a large scale was commenced, it has been intimated that it would be interesting to many members to know in what position the matter now stands. The more strictly scientific aspects of the question having been already treated of at various times, it is only proposed at present to give a very brief *résumé* of the technical results obtained at some of the leading dephosphorizing works, with the view of afford

*Paper read at the Autumn meeting of the Iron and Steel Institute.

ing members the necessary data for drawing their own conclusions as to the technical and economical status of the dephosphorizing process, and giving some materials for forming a judgment on the relative advantages of manufacturing iron by the fluid or ingot processes as compared with the puddling or piling process. It is to be premised, however, that, as there are at present in operation only three works in which the plant has been specially arranged to meet the requirements of the new process (none of which are as yet entirely completed), it is obvious that the average results here given are very far indeed from representing the economical practice likely to be obtained in new or specially adapted plants.

The data here given are based on the results obtained in the present current manufacture of dephosphorized steel, which amounts to between 27,000 and 29,000 tons a month. It may be added that the make for November, and probably for October, will considerably exceed 30,000 tons, or say at the rate of 360,000 tons a year; while in the course of the next few months, twelve more converters, now nearly finished, will come into operation, bringing the yearly make up to considerably over half-a-million tons. With regard to the question of production, it may be noticed:—(1) That at present, in the modified Bessemer process, the production of steel per lining is considerably less than in the old process, and that, therefore, the vessel plant, or the facilities for changing the vessel, should be increased for a given make. (2) That the make per unit of blowing and hydraulic engine power (and in consequence per unit of boiler and crane capacity) is substantially the same for both processes, and that, therefore, no increase in engine, boiler, or crane power is required for the dephosphorizing Bessemer process. As an illustration of the actual present productive capacity of old works modified for the new process, it may be mentioned that there are now at work in Germany two three-vessel basic pits, each regularly turning out twenty-four or more charges per twenty-four hours, which probably equals the full average of English practice with two-vessel hematite pits. This is the more remarkable as one at least of these pits is a very old and contracted two-vessel pit into which a third vessel has been squeezed. At another German works, with an old two-vessel basic pit, which works on day turn only, the average basic output is eleven charges in the twelve hours; while at a fourth works with an old two-vessel pit, twenty-two casts are regularly obtained per twenty-four hours.

The interest and redemption of the cost of a third vessel and its adjuncts would amount to a charge of about $1\frac{1}{2}d.$ per ton of steel produced. With the Holley system of removable shells there would seem to be no reason for anticipating any difficulty in obtaining from a single two-vessel basic pit any amount of steel that could be handled, or say at least fifty charges per double shift. In America a still larger production is expected from the new basic works. The durability of linings is intimately connected with the subject of productive capacity. In present practice the necessity for considerable repairs to the lining arises after from 35 to 90 blows. Thus it appears from the returns from various works that more or less extensive repairs are required on an average after 70, 60, 45, 40 and 60 charges respectively, or say an average of 56 charges. Practice varies much as to the mode of conducting these repairs. There are very important advantages in the system worked by Mr. Richards, of performing them with liquid lime-tar without cooling the vessel. This enables a badly-worn lining to be made as good as new in less than fifteen hours, as a maximum, after the last blow. In some works, when a vessel is badly worn the whole lining is knocked out and replaced; in most, however, the more economical mode of merely renewing the worn portion is employed, and an absolutely new lining is only put in after many months' working.

Not less important than the durability of linings is that of durability of bottoms. The average number of blows per bottom as reported by ten works is as follows: $8\frac{1}{2}$, 21, 13, 14, 18, 12, 14, 15, 12, or an average of over 14 blows. In nearly all cases only pin bottoms are used, so no tuyeres are replaced. The average would be higher if only the results of the past few weeks were taken. In many cases lime bottoms have run for

24 heats, and even over. The average duration of silica bottoms in England would appear to be under 11 blows, the best average being 14, and the lowest 9, besides replacement of tuyeres. Perhaps, however, the best criterion of the relative durability of basic lining material is afforded by the consumption of refractory basic materials for linings and bottoms per ton of steel produced. Unfortunately, reliable figures on this head are not always obtainable. The following represents the total consumption of basic refractory material (in the only works in which trustworthy account seems to be kept), in kilogrammes per 1000 kilos (1 ton) of steel: 45, about 40, 38, 70, or a mean of 48 kilos, or rather under 1 cwt. per ton of steel. The 70 kilos being in a new works not yet in regular work, it may be assumed that 48 kilos is more than the actual mean, which is probably under 45 kilos. The consumption of gannister and tuyeres in the hematite process is probably about 30 kilos. The consumption of coal in the burning and shrinking of the calcareous refractory lining and bottom material varies very greatly, being now considerably less than in early practice. Thus, for the production of a ton of prepared refractory basic material, the consumption of coal varies between 17 cwt. and 3½ tons at different works, being 2 tons, 3 tons, 3½ tons, 17 cwt., 20 cwt., and 22 cwt. At the works, where the cupola mode of preparation is adopted, the consumption of coke is 21 cwt., 18 cwt. and 15 cwt. With good firing arrangements and regular work, there seems no difficulty in obtaining a ton of lining material with a consumption of considerably less than 24 cwt. of coal, or say 16 cwt. of coke.

At the average cost of limestone and coal or coke in English steelmaking districts, the maximum average cost of basic lining material would be considerably below 27s. a ton; in some it would be below 20s. The cost has been reduced already very much below the first figure in several existing works, and in one at least below the second. Taking as an average 1 cwt. of basic material (including tar) per ton of steel made, the cost of material would be about 1s. 8d. per ton of steel produced. Should it prove practicable to commercially produce magnesia at a very low figure, this may also prove a useful material. The consumption of lime for additions varies between 13½ and 17½ per cent. on the weight of the pig used—say, an average of rather over 15 per cent. on the steel, or 3 cwt. per ton. The result of recent trials makes it probable that a little over 2 cwt. may prove sufficient. The slag produced in conversion is in all new works allowed to run direct into a slag bogey, so that there is no handling of slag at all. The composition of the slag, *i. e.*, its content of iron, manganese, lime, magnesia, and phosphorus, is such as to give it in the blast furnace—where it is used in all works having blast furnaces—rather more than the value of an equal weight of limestone.

The loss of metal, including remelting (when practiced), varies considerably, being in all cases in excess of the loss obtained in the hematite process. The absolute loss reported from eleven works is 14, 13, 16½, 16, 16, 15, 15½, 11, 13½, 17, and 19 per cent. respectively, or an average of 15 per cent. There is, however, reason to believe that the 17 and 19 per cent. losses reported are abnormal, and the latter, reported by a new work for the first few months' working, is probably incorrect. The loss from shots of metal being entangled in a somewhat cold slag is always exceptionally large at the commencement, owing to slow and therefore cold working, as well as to bad cupola working. The average loss in conversion in English hematite practice is probably about 12 per cent. The duration of the blow, including the after-blow, varies from thirteen to twenty-five minutes, averaging about eighteen minutes. In one case, with 3 per cent. of phosphorus, the total blow averaged under ten minutes. This does not include sampling, which, when practiced, usually occupies three or four minutes more. The sampling period would in America be doubtless utilized in blowing the second vessel. Blast-power sufficient to finish a blow in about fifteen minutes is desirable. The average pig used in various works varies in composition as follows: White iron is generally preferred; at Eston, however, Mr. Richards blows white, grey, and mottled indifferently, all direct from the furnace. Only direct working is carried on at Eston and Creusot, and mixed

direct and cupola working at two other works.

	1.	2.	3.	4.	5.	6.	7.	8.	9	10.	11.
Phosphorus	1.75	2.00	2.5	2.5	2.5	2.	2.2	3.00	2.	2.	1.0
Silicon... ..	1.2	1.0	.5	.5	–	.70	.80	.50	.70	1.3	1.00
Manganese.	.35	1.00	2.00	1.7	1.00	--	1.2	2.0	1.0	1.7	1.6
Sulphur....	.10 to .2										

All these varieties, which are the average of the charges used at the several works, work well, but considerably wider limits of composition are actually employed.

As to the quality of steel produced, the rapid extension of its employment for every purpose for which Bessemer steel has ever been used (excepting, perhaps, the manufacture of Bessemer tool-steel) is the best evidence. That dephosphorized steel is even superior to hematite steel for certain purposes, such as boiler plates and wire, is now pretty well agreed. The total number of converters at present regularly working on phosphoric iron is thirty-six, of which, however, eight or nine are of less than four tons capacity. Thirty more converters specially designed for the process are now under construction. Several Siemens furnaces have been in regular work for some time, but details of their operations must be reserved for the present.

If no formal acknowledgment is made by name to the many able co-workers in Germany, Austria, France, Belgium, and England, who have contributed so largely to the development of practical dephosphorization, and to furnish materials for this note, it is only because acknowledgments are due to so many that it would be invidious to particularize a few. As, however, Mr. Richards is absent, it may be permissible to renew the expression of a feeling of deep indebtedness to him—a feeling in which all interested in dephosphorizing progress will certainly join.

ON A BAROMETER FOUNDED ON THE EQUIVALENCE OF HEAT AND PRESSURE ON THE VOLUME OF A GAS.

By C. DECHARME.

From "Comptes rendus de l'Académie des Sciences," Abstracts of Institution of Civil Engineers.

The volume of a gas placed under determinate conditions can be reduced by the same quantity either by increasing the pressure or diminishing the temperature. In the same way the volume may be increased by a diminution of pressure or elevation of temperature. There must therefore be a temperature capable of producing upon a given gaseous mass the same change of volume that a given pressure will produce upon it, and *vice versa*. It is proposed to formulate and represent graphically this equivalence, in order to make it serve for the determination of the atmospheric pressure, the volume and temperature of the confined gas being known.

If V_0 represents the volume of a gas at the temperature 0 and the pressure H_0, and V the volume at the same temperature and the pressure H, thus, according to Boyle's law

$$V = V_0 \frac{H_0}{H} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

Again, according to the law of expansion of gases (the pressure remaining constant)

$$V = V_0(1 + a\,t) \quad . \quad . \quad . \quad . \quad . \quad (2)$$

a representing the coefficient of expansion, and t the temperature.

Equating these values of V expresses the fact that pressure and heat successively applied to a gas, bring it to the same volume, *i.e.*,

$$V_0 \frac{H_0}{H} = V_0(1 + a\,t),$$

$$\text{whence } t = \frac{H_0 - H}{Ha} \quad . \quad . \quad . \quad . \quad (3)$$

Make $V_0 = 1$, the formulas (1) and (3) may be applied to the special cases of atmospheric conditions, that is to pressures varying from 710 millimeters to 790 millimeters, and to temperatures from $-25°$ C. to $+40°$ C., between which limits Boyle's law may be considered as rigorously exact, and the coefficient of expansion as constant and equal to 0.00367. Make $Ho = 1$ atmosphere = 760 millimeters, and finally, after substitution of V in 3, we obtain

$$V=\frac{760}{H} \text{ and } t=\frac{V-1}{a}=\frac{V-1}{0.00367}.$$

The instrument employed consists simply of a mercury or alcohol thermometer, and an air thermometer for measuring the volumes of the gas corresponding to the observed temperatures. The details of construction are given in the original memoir presented to the academy.

The unit volume V_0 having been experimentally determined at the normal pressure, the volumes V of the gas at various pressures H, and the equivalent temperatures are calculated by means of the preceding formulas. By this means a numerical table is obtained, which can be represented graphically by means of a curve C_0.

If the temperature remained at 0, the pressure alone affecting the volume of the gas, it would suffice to find the pressure, to read this volume on the air thermometer, and to follow on the diagram the horizontal which bears the number of the observed volume; the point of junction of this horizontal with the curve C_0 belongs to the vertical corresponding to the desired pressure.

But the temperature being generally other than 0, the volumes V' corresponding to the various pressures are obtained by means of the formula $V'=V(1+at')$; if $t'=10$ for instance $V'=V\times 1.0367$, or in other words each value of V of the first table must be multiplied by 1.0367. The temperatures equivalent to the pressures will be calculated by the formulas $t=\frac{V'-1}{a}$. In this way a curve C_1o will be obtained, and other curves in an analogous manner.

To find the pressure, the actual temperature on the ordinary thermometer, and the volume on the air thermometer are observed.

Then taking the diagram, the curve corresponding to the observed temperature is followed until the horizontal line of volumes is reached, the pressure is found on the equivalent vertical line. Thus if $t=10°$, $V=1.06$, H will be found to be 743.7 millimeters. For intermediate temperatures, the position of the corresponding lines is easily observed, and the pressure to within one-tenth of a millimeter.

This instrument may be called absolute, as it gives the real pressure without further correction, and if the curves are traced for every 2° on a convenient scale, it becomes an instrument of great precision.

REPORTS OF ENGINEERING SOCIETIES.

American Society of Civil Engineers.—The last number of the "Transactions" contains the following papers:

No. 227. Repairs of Masonry. by O. Chanute.

No. 228. Strength and Ductility of the Copper-tin-zinc Alloys. By Robert H. Thurston.

Engineers' Club of Philadelphia.—The first meeting of the season was held on October 15th, 1881.

The Secretary exhibited, on behalf of Mr. J. Milton Titlow, screws which had, for 6¾ years, held together three 2-inch courses of yellow pine planks in the floor of Fairmount Bridge, Philadelphia, which planks had been treated in some manner with creosote. The screws in question are much corroded, the original diameter being diminished about ⅓ at the middle of the screw, where the fiber of the iron is distinctly exposed. It seemed, however, to be the universal opinion of the members present, that the corrosion was due entirely to the presence of water between the planks, and not at all to the creosote oil, which would preserve rather than destroy the iron

The Secretary exhibited copies of a drawing which had been made by a method giving more economical and better results in many instances than the ordinary blue process. Mr. Frederic Graff stated, in this connection, that the ordinary letter-press was the invention of Watt, and that the original was still in existence.

The Secretary read a detailed description of the moving of the Hotel Pelham, at Tremont and Boylston streets, Boston, for the purpose of widening Tremont street. This hotel is built of freestone and brick, 96 and 69 feet frontage. The Boylston street wall is supported on 8 granite columns 12 ft. high, 3 and 4 ft. square. There is a basement and seven stories above the sidewalk. Height above tramways on which it was moved, 96 ft. Weight, 5,000 tons, exclusive of furniture, which was not disturbed during removal, as also were not the occupants of the stores on first floor and some of the rooms, the various pipe connections being kept up with flexible tubes. Careful experiments with models showed that if the lower part of the building was firmly braced, there was no danger of shifting in the parts above. The general arrangements consisted of heavy and substantial stone and brick foundations for iron rails and rollers, and the building was forced to its new position by 56 screws, 2 inches diameter, ½ in. pitch operated by hand against timbers arranged to uniformly distribute the pressure against the

building. Much care and ingenuity was displayed in the details of the arrangements and work. Two months and twenty days were occupied in preparation. The moving itself was begun on August 21st, and finished on August 25th, but the actual time in moving was but 13 hours and 40 minutes. The greatest speed was 2 inches in 4 minutes. The hotel moved about ⅛ inch at each quarter turn of the screws. The whole distance moved was 13 ft. 10 inches. 4,351 days labor was required for the work. The whole cost was about $30,000. This is the largest building that has ever been removed, although larger have been raised, which latter is a much simpler and less risky operation. The complete success of this undertaking is shown by the fact that cracks, which existed in the walls prior to removal, were not changed by the operation. Paper was pasted over them before commencing, that any change might be seen.

President Strickland Kneass exhibited a drawing which had been sent to him by telegraph during his recent visit in Europe.

Prof. L. M. Haupt exhibited a note book, loaned by Mr. John C. Trautwine, containing many complete and beautiful sketches of bridge construction, notably of the celebrated Wernwag Bridge, which crossed the Schuylkill at Callowhill street.

American Society of Mechanical Engineering.—The annual meeting of the American Society of Mechanical Engineers was held, Nov. 3, in this city.

The programme consisted of an afternoon and evening session on Thursday, and a morning and afternoon session on Friday. The papers read were as follows: "A Mill Floor and its Supports," by C. J. H. Woodbury; "Fire Protection of Mills," by the same gentleman; "A Self-Packing Valve," by H. F. J. Porter; "Standard Weights and Measures," by Mr Partridge; "A New Method of Keeping Drawings," by Charles T. Porter; "Observations on Railway Structures from Ohio State Railway Service," by Prof. S. W. Robinson.

ENGINEERING NOTES.

The Proposed New Tay Viaduct.—The plans of the proposed new Tay bridge, prepared by Mr. W. H. Barlow, C.E., are now being exhibited at the North British Railway offices, Edinburgh, for inspection by intending contractors. The new bridge, which is to be built on the girder principle, will commence on the south side, about 16 feet west of the former bridge. At this end four brick arches are shown next the shore, each having a span of 50 feet. The girder work then commences with a span of 118 feet from center to center of the piers, and is continued with ten spans of 129 feet, and thirteen of 145 feet from center to center of the piers, until navigable portions of the channel are reached. Here there are thirteen wider spans, eleven being each 245 feet, and two 227 feet each. Of these spans the first four are carried to the greatest height of the structure, and give 77 feet of clear headway above high-water mark. From this point the line of the bridge commences to fall towards the north or Dundee side, at a gradient of 1 in 114, there being one span of 162 feet, ten of 129 feet 6 inches, and one of 127 feet 6 inches. These spans carry the bridge on to the commencement of the curve towards Dundee; and twenty-five more, each of 71 feet, take the structure to the side of the proposed extension of the esplanade. Several other spans take the bridge on to the point where it is run into the level of the existing arches. The bridge is to be constructed for a double line of rails throughout. The foundations in the river bed will be formed of two wrought-iron cylinders, placed at a distance of 26 feet apart from center to center, and filled with concrete These cylinders rise to the height of within 2 feet of low water mark, where brick will be used, filled in also with concrete. This brickwork is to the height of 8 feet above high-water mark, at which level the cylinders are connected, and made to form a solid foundation, topped with a course of ashlar. Rising from this foundation, two piers are formed of wrought-iron pillars braced together, and encased with iron plates of from three-eighths to seven-sixteenths of an inch in thickness. The piers, thus constructed, are connected with each other near the top, and the whole has the appearance of a high and strong-built arch on which to place the girders. The principal piers are octagonal in shape, with a diameter varying from 11 feet to 14 feet 6 inches. The spans are each composed of four girders, with the exception of the higher spans. These are of two girders connected together, top and bottom, with bracing and flooring. The bridge throughout its whole length will have a parapet of between 5 feet and 6 feet in height, forming a wind guard. The depth of each girder on the piers is 16 feet 6 inches. The middle girders are 28 feet 9 inches in the center and at the ends 20 feet 3 inches. They are of hog-back lattice form. The other girders are of plain lattice work, and are all connected by cross bracing, on the top of which the train travels as it did on the old bridge. At the high girders the train travels between them. The platform of the bridge is of wrought iron throughout. In the construction of the new bridge, the old one will be sufficiently near for anchorage and cranes.

The Channel Tunnel.—The work of removing the machinery from the Abbott's Cliff heading to the shaft at Shakespeare's Cliff, in connection with the Channel tunnel experiments, is now complete, having occupied upwards of two months, and boring operations will probably be commenced again next week. The scheme is now in the hands of the South-Eastern Railway Company, who, we understand, have entered into a contract for the drilling to be extended another mile. For the present the boring will be continued in the direction of Dover. Several workships and sheds, have been erected at the mouth of the shaft and a powerful engine has been fitted up. The arrangements are now much more complete than formerly, and are calculated greatly to

facilitate the progress of the work. The cuttings from the face of the chalk are carried to the rear of the engine by cups, and afterwards conveyed in an iron skiff from the engine to the mouth of the shaft by means of pulleys attached to a drum, which is worked by machinery. With the present arrangement, the same amount of work will be able to be performed with a considerable reduction of labor, about thirty men only being required instead of double that number, as at the Abbott's Cliff heading.

A recent report by Signor Frescot, one of the engineers of the railways of Upper Italy, gives some interesting facts with regard to ventilation in the Mont Cenis Tunnel. The Mont Cenis Tunnel is 12,500 meters in length, and has a capacity of 500,000 cubic meters. The mean temperature is 25° C. In winter this causes sufficient natural ventilation, aided by the difference of altitude of the two extremities —132.5 meters. But in summer the external and internal temperatures are often equal, and artificial means of ventilation have to be adopted. The passage of twelve trains per day, the *Times* says, may be assumed containing 2500 passengers, each passage through occupying half an hour. The locomotives burn anthracite, which produces less carbonic oxide than coke, and the combustion is rendered as complete as possible. Now it is estimated that the average total production of carbonic acid in the tunnel per day is 6987 cubic meters, of which 6930 cubic meters are attributed to the trains, the rest to servants, passengers and lights. The normal proportion of carbonic acid in the atmosphere varies from 0.003 to 0.005. People can live in an atmosphere containing as much as 0.005. It has been proposed to attain in the Mont Cenis the same degree of purity as in our Metropolitan Railway, or 0.0015 of carbonic acid. With this view, a large centrifugal ventilator has been set up on the Bardoneche side; it is driven by water, which is abundant there. The entrance of the tunnel is closed by a door, which the trains open on passing under the arch, and close after passing. In winter, and also during some fresh nights in summer, the machine can be stopped, and any necessary repairs made. In addition to the ventilator, there is in use the compressing and aspirating apparatus that was employed in making the tunnel. Notwithstanding these means and care bestowed on the fires of the locomotives, there is reason to fear that the present ventilation would prove insufficient in case of even a small increase of the traffic.

RAILWAY NOTES.

The following accidents occurred upon the premises of the railway companies of the United Kingdom during the first six months of this year, in which the movement of vehicles used exclusively upon railways was not concerned, namely: 51 passengers injured whilst ascending or descending steps at stations; 18 injured by being struck by barrows, falling over packages, &c., on station platforms; 17 injured by falling off platforms; and 36 injured from other causes. Of servants of companies or contractors, 3 were killed and 469 injured whilst loading or unloading, or shunting wagons; 156 were injured whilst moving or carrying goods in warehouses, &c.; 1 was killed and 126 were injured by the falling of wagon doors, lamps, bales of goods, &c.; 241 were injured by falling off, or when getting on or off, stationary engines or vehicles; 10 were killed and 125 injured by falling off platforms, ladders, scaffolds, &c.; 1 was killed and 126 injured by stumbling whilst walking on the line or platforms; 62 were injured whilst attending to stationary engines in sheds; 20 were injured by being trampled on or kicked by horses; 3 were killed and 280 injured whilst working on the line or in sidings; and 106 were injured from various other causes. 2 persons who were transacting business on the companies premises were also killed and 51 were injured; making a total in this class of accidents of 21 persons killed and 1951 injured. The total number of personal accidents reported to the Board of Trade by the several railway companies during the six months amount to 518 persons killed, and 3960 injured.

Electric Railways.—The electric railway, we hear from Berlin, is there proving to be so great a success, that it is already in contemplation to apply the same mode of moving trains to the St. Gothard Tunnel and to the Metropolitan Railway.

With regard to the St. Gothard Tunnel, it may be presumed that the coast is tolerably clear, and that if it can be shown that electric propulsion is, all things considered, likely to prove the best and cheapest, Messrs. Siemens, on the one hand, and the directors on the other, will thrash the matter thoroughly out.

With regard to the Metropolitan Railway, the case is different. There all the arrangements are made, and are in excellent working order. More than £400,000 have been expended on working stock. Not an interval of five minutes during eighteen hours out of the twenty-four passes without a train running over the rails. Before, then, any question can be raised as to change in system here, two things are requisite. First, the electric system must be shown to be as reliable and as manageable as the locomotive system; secondly, it must be shown to be considerably cheaper.

We are not advancing this statement with the view of throwing cold water on an invention which, if fully successful, will be a success of a very high order. We are only desiring to direct into the groove of practical inquiry that energy that may otherwise be wasted in vague and profitless speculation.

As to the first point, the practical working of the line, we have nothing at the present time to say. Details will, no doubt, be forthcoming, and if they prove satisfactory, experiments will in due course follow, made on some branch line or short portion of railway, where positive results can be obtained without interfering with actual traffic. We mean, of course, in this country.

What we wish to discuss is the limit of pos-

sible advantage, or the reverse, in a pecuniary sense, to be derived from the subsittution of the electric-motor power for the heavy locomotives which now propel the trains of the various subterranean railways through the metropolis.

On this highly-important subject we should be able to speak with more precision if the official returns of the English railways furnished the details of work actually done in the conveyance of traffic, whic are necessary in order to inform the shareholders of what part of their business does, and what does not pay. But notwithstanding the persistent refusal of this information, we are able, by working from the details given by the directors of foreign and colonial lines, at all events to lay down certain limits within a trifle of exactitude.

The average cost of moving 100 tons of loaded train for one mile on the railways of the United Kingdom in 1879 we estimate at 20.76 pence, out of which 5d. was the cost of locomotive power alone. From the data furnished by the Blackwall Railway we arrive at the conclusion that out of this 5d. per 100 tons taken one mile, 4d. was expended in moving the locomotive and a penny in moving the train. This 4d. per 100 tons per mile, or approximately per train mile, is therefore the limit within which any possible saving must be confined.

On the Metropolitan lines, however, the cost of locomotive power is greatly increased by the frequent stoppages, the high speed which it is necessary to get up between the stations, and the tearing action of the brakes, alike on the engines, the trains and the rails. We think it will be found that it would not cost more for locomotive power and maintenance to run a metropolitan train for twenty four miles straight on end without stopping, than to run the usual stopping train from Moorgate street to Praed-street. Thus while, owing to the good loading and the consequent low tare, the Metropolitan lines are worked at a lower percentage on their receipts than any other in the country, they cost more per mile per 100 tons than any other. The great weight of the engines, which is a necessary consequence of the high speed and numerous stoppages on the Metropolitan lines, is such as to bear a far higher proportion to the weight of the carriages than would be otherwise needful. An estimate which we made on the best data accessible in 1875, gives a cost of 45.7 pence per 100 tons per mile, or about 2¼ times the average of the English lines. For locomotive power, maintenance and repairs alone, the cost was 17.9 pence against 11d. on the average of the United Kingdom.

For maintenance and repairs, on the average of the United Kingdom, as aforesaid, the cost is 6.6d. per 100 ton miles of load conveyed. This is only 1.2d per unit more than we arrived at for the Metropolitan line. We thus have a cost of 11.3d. for locomotive power and excess of charge of repairs, on which saving would be effected if it became possible to substitute the cheapest mode of applying power hitherto indicated for the locomotive. And if we take the resistance cost (or lowest ascertained cost) at 1d., there is a margin of 10.3. per 100 ton miles out of which saving is conceivable. If we roughly allow the Metropolitan and Metropolitan District trains to average 100 tons each, load and all, a saving of 10d. per train mile would amount to more than £70,000 per annum, or to an addition of 14½ per cent. on the net profits of the two lines.

By the test of reduction to £. s. d., therefore, the conceivable saving to be effected by the replacement of the locomotive by electric propulsion is one of a magnitude well worth the attention of mechanical men, as well as of the engineers and managers of railways. Attention, of course, will be first given to those lines in which it is desirable to escape from the nuisance caused by the products of combustion. Through a long tunnel, if the passage of the locomotive could be avoided by any means that did not either reduce the certitude or increase the cost of the transit, a considerable advantage would be assured. As to the Metropolitan lines, the special cost of the sudden starting, high speed and sudden stopping of the trains is such that the advantage of doing without a locomotive would be considerably more than on ordinary railways. There is this to be urged in favor of experiment with a view to decide these points that we have named as open, that just where the advantages of superseding the locomotives would be the greatest, the margin of possible saving would also be the greatest. That so much, or that any, saving is yet shown to be possible we do not say, for we do not know. But there is a great presumption in favor of prompt and exhaustive inquiry.—*Builder.*

IRON AND STEEL NOTES.

On the Application of Solid Steel to Small arms, Projectiles, and Ordnance Manufacture—This paper, read before the Iron and Steel Institute, was intended to give the results obtained with cast steel containing silicide of manganese. The steel with silicide of manganese, besides the security which it presents in its homogeneity, preserves, when it has been hammered or rolled, an increased limit of elasticity, with a strong tearing strain and a good elongation. It is not necessary to seek for anything more in the manufacture of the barrels of guns. M. Nobel, who worked quite recently at the manufactory of arms at Ijef, near to Perm, has used steel with the silicide of manganese, made according to the process of Terrenoire, in the manufacture of the barrels of guns for the Russian army. The steel without blowholes in small ingots is drawn under the hammer alone. It then possesses the following mean composition :

Carbon	0.120
Silicum	0.234
Manganese	0.527
Sulphur	0.020
Phosphorus	0.109

This analysis answers to the best tests, and presented the following resistance to trials :

Diameter of the test 18 *mm.* = 0.7*in.*

	Kilos.	Lbs.
Limit of elasticity	30.13	= 66
Tearing strain	65.50	= 143
Elongation per cent. measure upon 200 mm	18.7	
Contraction per cent.	48.30	
Tearing strain according to the section contracted	128.30	= 282

It was claimed that the tests given proved that the steel of Bofors, applied to the barrels of guns, shows itself superior not only to that of Swedish, Bessemer, or Siemens-Martin manufacture, which has been subjected to experiments, but especially to that manufactured at Witten, of which the quality is as good. Not a rupture has taken place in it, notwithstanding the excessive charges. Before quitting the works of Bofors, the author mentioned the tests of artillery cast in steel. The Bofors Company has commenced to cast a field gun of 9 cm. bore. This cannon, which resisted the severest tests, is the admiration of artillerymen. The Swedish artillerymen wished to undertake at Bofors the manufacture of steel tube castings for cannon of 12 cm. steel hoops. The commencement of this manufacture was beset with difficulties, and success only began when they gave to the iron mould or shell a thickness of 150 mm. at least. The first four tubes, cast with a shell of only 25 mm. thick, showed numerous cracks, which made them useless. To avoid this it was only necessary that the mould in which the casting was made should be red hot; it appears that the rapidity of cooling plays an important part in the physical structure of the metal. In fact, it is not enough that it should be without blow-holes; it is also necessary that in the cooling no cracks should be produced. Dealing with the application of metal without blow-holes to the manufacture of armor-plates, and of projectiles to pierce them, the author said that the first question is still under consideration. It cannot be said that it is completely solved, yet a great deal has been done, and in France they are now able to obtain cast plates with nearly as much power of resistance as forged steel plates, at a price considerably less. The mixed plate of iron and steel welded together has presented a resistance so superior that the question ought to be studied anew, and they are now proceeding with some trials of mixed plates of iron and steel without blow-holes welded together. As to projectiles of cast steel—shells or solid shot—he announced some very decisive results. France and Russia now employ no other material for their naval artillery. These two Governments, starting on the principle that in war the straight target will be the exception, and the oblique target the rule, use for their projectiles of penetration the material which gives the best resistance to the oblique target—cast steel without blow-holes obtained by the silicide of manganese.

ORDNANCE AND NAVAL.

Deck Armor for Ships.—On September 13 a series of experiments was conducted at Eastney, near Portsmouth, with the object of determining the best kind of plating for the deck armor of ships of war. According to the *Times* correspondent, a great mystery was made of the occasion, and Colonel Mawbey, of the Royal Marine Artillery, who, in the absence of General Prince Edward of Saxe-Weimar, is in command of the garrison, was furnished from the Admiralty with stringent instructions as to who were to be permitted to be present at the firing. Among those who were admitted to the range were Mr. Barnaby, Director of Naval Construction, Rear-Admiral Herbert, Director of Naval Ordnance, Mr. White, Assistant Constructor of the Admiralty, Captain Codrington, Commander Beaumont, and Lieutenant Nichols of the "Excellent" gunnery ship, Mr. Nordenfeldt, and representatives of the manufacturers of the armor plates generally. Two naval attachés were granted permission to attend—namely, Captain Racchia, on the part of Italy, and Baron Barnchoff, on the part of Sweden. Similar plates to those fired on the 13th, both as regards thickness and manufacture, were some time ago subjected to the ordeal of angular fire at Whale Island, but in this case the attacking guns were Hotchkiss and Nordenfeldt machine guns, which, however formidable they may be against unarmored ships and torpedo craft, would be perfectly harmless against deck armor in position. For the first time in the history of naval construction, this armor was submitted to the roughly practicable assault of armor-piercing guns at practicable angles of inclination and elevation; and yet it is not too much to say that, with the exception of the large class of ships, which are either completely protected or are belted with ponderous side-armor, the efficiency of our latest ironclads depends almost entirely upon the integrity of the deck armor, for not only are the vital parts of the ship defended against vertical fire by an armored deck, but reserved buoyancy of the unarmored ends and the stiffness of the ram are secured by the same means in the ships of the "Comus" class, a largely increasing fleet. There is an under-water steel deck wrought over the engines, boilers, and magazine, dipping forward to the center of the spur, and with a raft body above, and Mr. Barnaby does not hesitate to say that, in virtue of its position as against blows of projectiles, this deck is as effective a protection for these parts of the ship as would be given by side armor. Even such armorclads as the "Inflexible," "Ajax," "Colossus," and "Nelson," which, so far as regards their defence against shell, are submitted as the permanent type of the ships of the future, have their armored division associated with protected ends. In the "Italia" and "Lepanto" the Italians have been even adventurous enough to dispense with side armor altogether, and to make them wholly dependent upon deck armor for their stability in action. The English Navy possesses no example of this type of vessel, but when it is considered that the "Polyphemus" and our most modern citadel ships will in ultimate circumstances be kept afloat by means of the reserve buoyancy secured by their steel decks, the importance of ascertaining practically the behavior of this protection under fire will

readily be understood. There were seven targets fired at, consisting of an ordinary iron plate, two of Sir Joseph Whitworth's compressed armor plates formed of hard steel scales, 14 inches square, and mechanically attached to mild steel backing, a plate of mild Landore steel, compressed plate manufactured by the Bolton Steel Company and by Sir John Brown and Co., and a steel-faced armor plate manufactured by Cammell and Co. upon Wilson's system. With the exception of one of Sir Joseph Whitworth's plates, which was 1¾ inches thick, each of the plates was 2 inches in thickness, and measured 12 feet by 4 feet. The targets were built to roughly represent the deck of a man-of-war. The bottom edge rested on the ground, and the plates were placed with an upward slope of 15°, being 5° for the roll of the ship, 5° for the plunge of the projectile, and 5° for the inclination of the deck. Each plate was bolted to an inch iron plate, representing the deck of a ship, the whole being supported by iron bulge beams and shored up by massive wooden balks. The range of fire was 100 yards, while the attacking guns consisted of the 18-ton 10 inch gun, firing a 404 lb. projectile with a battering charge of 70 lbs., and the 12 ton 9-inch gun, firing a shot of 255 lbs, with a 55 lb. charge. To assail 2-inch plates with such weapons seemed on the face of it not unlike threatening a fly upon the wheel, or uplifting a Nasmyth hammer to crack a nut. And so it proved in the result. It was, it is believed, originally intended that the ordinary iron plate should be made to serve the purpose of a unit of comparison as to the different degrees of resistance displayed by the various plates. The guns were to be first fired with slow velocities, and when the amount of energy just sufficient to penetrate the iron target had been practically ascertained, the other targets were to be brought under fire. In the experiments of the 13th this very necessary preliminary seems to have been omitted or lost sight of, with the upshot that in the end it was found that no comparisons were possible from the fact that the whole of the plates were destroyed by the superfluous power of the attacking force. With conspicuous impartiality, the whole of the plates were served precisely alike. The firing began with full charges from each gun, and ended in the same way, the result showing that the artillery proved too strong for the plates at the given range and angle, and that the latter, whether constructed of iron or steel, or iron and steel, would in action have been unable to protect the crews of our ships from a mitraille of bolts and miscellaneous debris. It was noticed, however, that in every round (and a round from each gun was delivered against each plate), the projectile was broken up on impact, deflected from its course, and scattered in the sea, and that in no instance was the target, though smashed, penetrated by the shot. The point having failed to bite the plate, the projectile seems to have turned over and holed the plate by a blow from its base. In only one case did the shot go through the plate.

BOOK NOTICES.

Publications Received.

Graphics of Rectangular Bridge Trusses: A new method. By Theo. Kandeler.

From the Institution of Civil Engineers, through the Secretary, Mr. James Forrest:

The Prevention of Waste of Water. By Thomas S ewart.

Explosions of Firedamp. By Prof. Haton de la Goupilhere.

Abstracts from Foreign Transactions and Periodicals. Vol. 66, Pt. 4.

The Education of Civil and Mechanical Engineers. By Henry Dyer, C.E., M.A.

Contributions to the Theory of Military Mining. Part II. By H. Hofer. Translated by Capt. Charles W. Raymond.

Portland Cement for Users. By Henry Faija, C.E. London: Crosby Lockwood and Co. Price $1.40.

This is essentially a guide to the buyer and user of Portland cement, and affords detailed advice regarding the points to be considered in making selections.

The contents of the book relate to the various qualities and tests in the following order:

Weight, Fineness, Gauging, Setting, Tensile Strength, Sand Test, Chemistry, General Remarks, Application of Cement.

The appendices, containing tables and descriptions of machines, occupy about as much space as the treatise itself.

The Kinematics of Machinery. By Prof. Alex. B.W. Kennedy, C.E. With an introduction by Prof. R. H. Thurston, A.M., C.E. (Science Series No. 54.) Price 50 cents.

Treatises upon the principles of mechanism are not common, and the few really standard works are too voluminous to encourage the novice who seeks first a knowledge of leading principles only.

This little book is reprinted from Prof. Kennedy's lectures, delivered at South Kensington. The lectures were prepared for students, and to explain the advanced methods of Reuleaux. They were first republished in this country in Van Nostrand's Magazine, at the suggestion of Professor Thurston, who explains in the introduction the reasons for placing a high estimate upon this little treatise.

Dr. Carl Sachs' Untersuchungen am Zitteraal, Gymnotus Electricus, Leipzig: Von Veit & Co. Price $9 60.

This record of electrical researches will prove of interest to the physiologist rather than to the practical physicist.

Results of an economic value from electrical

eels are no more to be expected than practical illumination from fire flies, but the experiments of those scientists who have labored to fathom the philosophy of the interesting phenomena, will be regarded with deep interest by many who have neither the inclination nor the skill to attempt similar researches.

The record fills a royal octavo volume of 440 pages, and is well illustrated.

PHYSICALISCHE DEMONSTRATIONEN. By Dr. Adolph F. Weinhold, Leipzig: Quandt & Händel. Price $8.10.

Dr. Weinhold is known in this country through his valuable work on "Physical Experiments." The present work will prove equally useful to the teacher of physics. The ground covered by the treatise is not essentially different from that of the previous work.

The illustrations are numerous (483 cuts and 4 plates) and are good.

MISCELLANEOUS.

THE report to the British Association of the committee on underground temperature, read by Professor Everitt at York, showed that during the past year observations were made at three places—at the East Manchester Coalfield, the Talargoch Lead Mine in Flintshire, and the Radstock Collieries, in the neighborhood of Bath. The Manchester observations were made in three pits of great depth, and the results were as follows: Depth, 2790ft., temperature 85.3 deg.; depth 1020ft., temperature, 62 deg.; depth, 1050ft, temperature, $62\frac{1}{3}$ deg. Assuming the surface temperature to be 49 deg., the increases were 29.3 deg. in 2790ft., or 1 deg. in 76.9ft., 13 in 1020ft., or 1 deg. in 78.5ft., and $13\frac{1}{3}$ deg. in 1050ft., or 1 deg. in 79ft. In Flintshire, with a surface temperature of 48 deg., an increase of 14 deg. was shown at 660 ft., or 1 deg. in 47 feet; while three pit observations made in the neighborhood of Bath brought out the following results: At a depth of 560ft. an increase of 11.7 deg., or 1 deg. in 48ft.; 810ft., 13 deg., or 1 deg. in 62ft.; and 1000ft., 13 deg. or 1 deg. in 77ft. Thus it would appear that the rise in temperature is more rapid in the older and harder rocks.

M. DE PEZZER has constructed a modification of the secondary battery of M. Planté, in which he has endeavored to obtain a maximum charge with a minimum quantity of lead. He uses for the negative electrode a very thin lead plate of about ½mm. thick, the positive plate being no more than ⅜mm. thick, projecting portions of the plates which serve for connections, are, however, somewhat thicker. Besides this, M. de Pezzer took two identical couples, each formed of two plates of lead of the same thickness, one of which, however, had twice the surface of the other. He then charged the couples by the same means, but arranged them so that in one case the plate with the larger surface should be the positive element, and in the other, the negative. By this means he discovered, by repeated experiments, that the couple in which the plate with the large surface was the negative electrode accumulated more electricity than the other couple. In four consecutive experiments the discharge of the couple with the large surfaced negative plate lasted at least an hour, whilst that of the couple in which the positive plate had the larger surface lasted but half an hour. Finally a couple formed of two plates equal in size to the two large ones of the above-mentioned couples gave an inferior result to that of the couple with the large negative plate. With these results to guide him, M. de Pezzer modifies the construction of the secondary battery as follows: Preserving the sizes of the plates given above, he makes the surface of the positive half that of the negative plate, at the same time making a certain number of incisions in the former. The arrangement of the plates is the same as ordinary; but, according to M. de Pezzer, his modification is capable of storing up the same quantity of electricity as a much heavier battery constructed in the usual way. The *Electrician*, quoting a French contemporary, says that M. de Pezzer promises exact figures on this point soon. M. Ducretet writes that he has obtained good results by using electrodes made of sheets of lead, having their surfaces covered with deep indentations, produced by a roller with indented surface. M. Ducretet says that these batteries form more quickly, have more energy, and are not so heavy as the ordinary ones.

THE American Consular Agent at Maracaibo describes a remarkable deposit of petroleum as existing between the Rio Tara and Zulia. Near the former there rises a sandbank about thirty-five yards in extent, and some ten yards in height. On its surface is visible a collection of cylindrical holes of different diameters, through which streams of petroleum, mixed with boiling water, gush out with great violence, accompanied with a noise as though two or three steamers were blowing off steam. Dr. M'Gregor states that from one of these holes, notwithstanding the difficulties of the position, he filled in 42 seconds a vessel containing 15 bottles, or as fast as four gallons per minute, or 240 gallons per hour, or 5,760 gallons during the 24 hours. A curious phenomenon, the *Times* says, has been occasionally seen in Venezuela ever since the conquest, consisting of a frequent lightning, which is observable from the bar at the entrance of the Lake of Maracaibo, close to the Island of Pajoseco, and which Colonel Codazzi, in his geography, attributes to the vapor ascending from the Cienega de Agua Caliente. This appearance, called by mariners "El farol de Maracaibo," is more probably due to the inflammable gas known by the natives as "El Inferno." It is possible that the supply of petroleum is abundant here and in the Republic of Columbia, where, between Escuque and Bettijoque, the laborers gather it up in handkerchiefs, which, when saturated, are squeezed out into barrels.